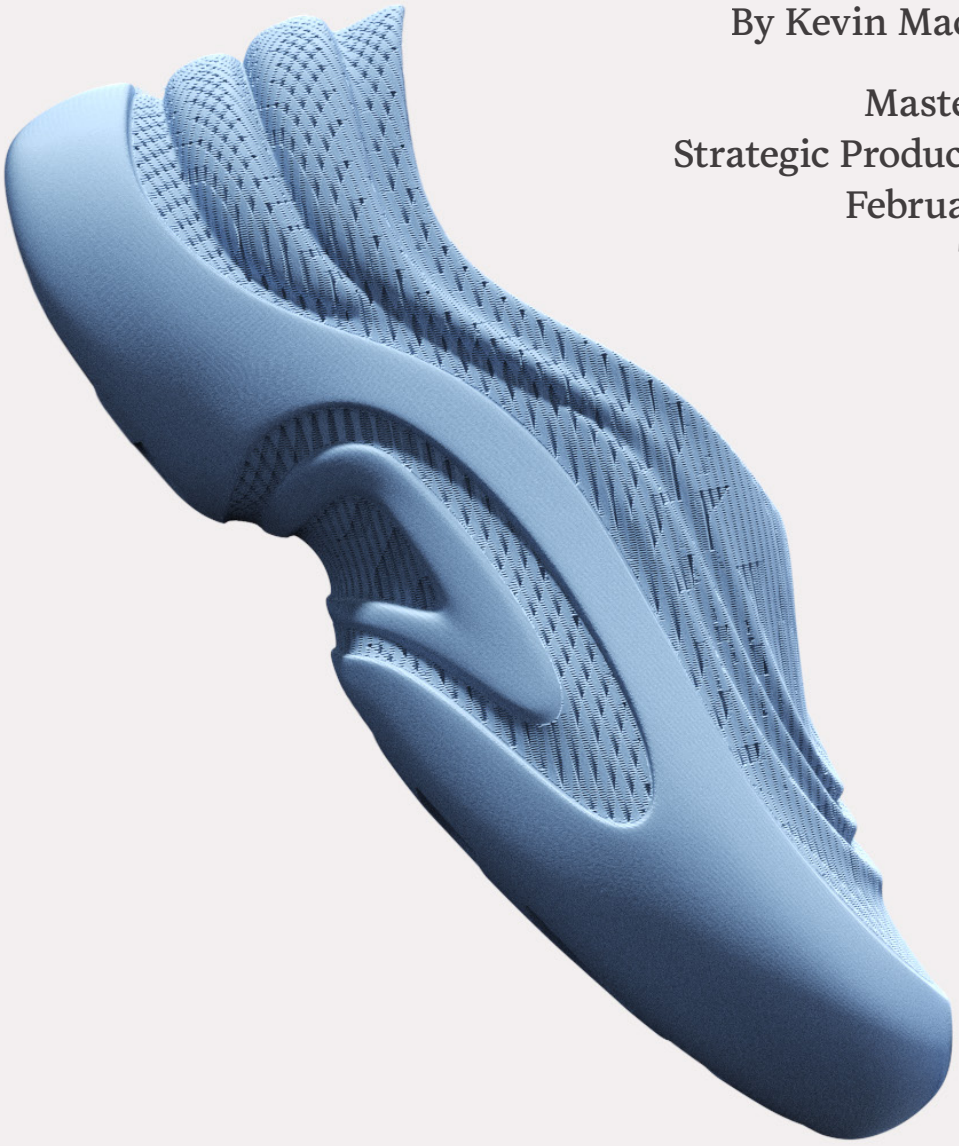
Design of a Circular Product-Service System for 3D Printed Children's Footwear

By Kevin Mac Donald



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A Personal Introduction

I have invested a large amount of my time over the past few years into footwear, sneakers more specifically. As a child, I was intrigued by shoes with crazy designs. I remember repeatedly going to the local Adidas store, where shoes were displayed with wings or teddy bears attached to them. Towards the end of high school, the influence of artists, designers and celebrities on footwear had started to become increasingly visible to me. I started hearing about people lining up outside shoe stores to get their hands on a pair of limited edition sneakers, to collect or resell them. For a couple of years, I was part of this community. As I went on to study Industrial Design Engineering, I started to become increasingly interested in the design and engineering of footwear. Over the past four years, my interest in footwear transformed into a somewhat more professional pursuit. In 2019, at a local footwear brand in The Hague, I had been given the opportunity to assist in designing their upcoming collection, and I was asked to explore the topic of sustainability in the footwear industry. This internship gave me taste of what it was to work in this industry, and I was hooked! In the years after, I kept improving my footwear design capabilities, and I decided to dive deeper into the topic of sustainability. In 2021, I worked with footwear manufacturers in Portugal, with the goal of developing my very first product. This was important to me as it allowed me to go through the entire footwear development process, and see first hand what challenges you have to overcome to develop a more sustainable sneaker. Throughout this two year journey, I had published my work and findings online, which had put me in contact with other people who were trying to make a dent into the footwear or fashion industry, and accelerate the shift towards a more circular economy. After a series of setbacks around the shoes I was developing and new information that I had found, I eventually decided to change my approach. For a period of six months, I focused on designing a shoe with a modular construction that would be easier to disassemble and process at end-of-life, in order to deal with the great amount of waste that is globally produced by the footwear industry. In that project, I built further on the insights that I had gained during my initial internship and the shoe I had developed in Portugal. During my stay at the Footwearology Lab in Barcelona, I was able to learn more about modular footwear designs, as well as computational design, and local and additive manufacturing processes for footwear. Inspired by the work I had done at the lab and seeing how companies like Zellerfeld were making great steps to scale up production of 3d printed footwear, I continued to investigate footwear that is made from one piece. This type of footwear was something that I had dreamed and written about during my initial internship in The Hague. This thesis was inspired by the amazing progress that has been made in recent years in the field of digital fabrication for footwear, and by all of the people I have met who are challenging the status quo and trying to create a greater footwear industry for tomorrow, with respect for people and planet. This thesis also incorporates my personal interest in the field of preventive, holistic healthcare and new systems and strategies that can help people to live more healthy lives.

– Kevin Sinclair Mac Donald

Acknowledgements

During the course of this thesis and the activities leading up to this final step in the Master's program of Strategic Product Design at TU Delft, I have met a large number of people that have helped me to eventually create the project that is in front of you. Hereby, I would like to thank every single one of them for inspiring, teaching and supporting me. I would not have been able to create this work without you.

First, I would like to thank my supervisors that have guided me throughout this thesis. I want to thank both Lise Magnier and Jo van Engelen for the great collaboration and their close involvement in this project. You have made this project a joy to go through and have supported and challenged me where necessary. Thank you for your openness to take on and refine this project, which started as a wild idea, but eventually took shape and, hopefully, will provide other people with insights that help them in their pursuits.

Second, I want to thank the people that I have met throughout my past years of venturing into footwear and sustainability. So many people are working on innovating and accelerating the shift towards a future industry that is better for people and our environment. I have great respect for all of you. Some of the people I have met along the way: Gülsün Borgwit, Nicoline van Enter, Bas Flipsen, Duncan van Norden, Luis Bugin, Anna-Lara Sigron, Jordi Montaner, Kedar Benjamin, Marina Aperribay, Matthias Zäh, Charlie Smith, Max van Bree, Matthea van Staden, Arthur van der Kroft, and the whole team of WEAR. To these and others I have met, I hope to work with you again, and keep going at it! You are all making a difference through the work you are choosing to do.

Third, I would like to thank all of the people that have participated in the interviews that were conducted for this thesis. Without your involvement, this project would not be what it is. Thank you for your excitement, for caring and for sharing your experiences. You helped to overcome my mental hurdles with regards to conducting interviews and engaging people in the process, and allowed this project to be grounded in reality.

Finally, I would like to thank all of my family and friends that have supported me before and during this project. I am the result of every person I know, and every interaction I have had. Finally, I want to thank my girlfriend for her bravery and changing my frame of reference for what is possible.

- Kevin

Executive Summary

3D printing technology is a rapidly growing field in the context of footwear production, and in combination with computational design and foot scanning tools and algorithms, this allows for a shift from mass production to mass customization of footwear. This thesis considers the design of a new circular product-service system for children's footwear, with the purpose of extending the benefits of mass customization to the target segment of children up to twelve years old, with their parents as key decision-makers in the footwear selection process. The development of this system also provides new insights for possible business opportunities for 3D printed footwear, and lays out opportunities and challenges around accelerating the shift towards a circular footwear industry.

A central aim of this thesis is to explore what constitutes a perfect fit for children's footwear, how 3D printed footwear can be used to overcome challenges related to finding a perfect fit, and what retail experience and services need to be provided to create a system that removes barriers and promotes healthy foot development, considering this essential for healthy lifelong mobility. In this thesis, fit is constructed of three elements: physical, identity and social fit. The tensions and relations between these forms of fit are explored and translated into a concept design consisting of three parts: a physical product, an in-store experience, and a mobile service. Together, these deliver a system that aims to remove the need to compromise on aesthetic value or physical fit, put the child at the center of the footwear selection process, and inspire and facilitate more pro-active consumption behavior of children's footwear. This project involved the creation of various physical and digital prototypes that were used to gain insights on key aspects of the proposed product-service system. Qualitative data resulting from exploratory customer research and user testing of the proposed concept, with parents as end-users, have resulted in a greater understanding of the technical and perceived challenges with regards to the implementation of such a new system for 3D printed children's footwear.

In addition, this thesis oscillates between two equally critical perspectives: that of the user and that of the system. Technical and perceived tensions between personalized footwear and reuse of pre-owned footwear are revealed, and opportunities for take-back systems and end-of-life solutions are discussed. Furthermore, opportunities for rapid product improvement and more detailed analysis of foot and gait development are explored, as a result of the circularity of the system.

A strategy for market implementation of the proposed product-service system is detailed, highlighting the opportunity to create a system that onboards users of 3D printed footwear from the very first steps, and creating a membership and subscription based approach. Key strategic partners are identified for the realization of the proposed system, addressing complexities of the system, strategic positioning along the product and service supply chain and the need for expertise, specifically in the areas of production and fit measurement. Finally, this research highlights several key areas of interest and opportunities for future research and development.

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01

Introduction of The Project

In this first chapter, the initial assignment and approach to the project are introduced. A description of the context and problem definition is followed by the scope and focus of this project, presenting an overview of the stakeholders that are involved. Furthermore, a set of initial questions and personal learning ambitions is formulated, introducing the literature review that is described in the following chapter, and the goals I have set for this project. Finally, this chapter details the approach and design methods that were used, and provides a visual overview of the project activities, project structure and report structure.

1.1 Initial Assignment

Context & Problem Definition
Scope & Focus
Initial Questions & Research Goals

1.2 Project Approach

Approach & Methodology

1.1 Initial Assignment

This section describes the context and problem defition to introduce the project. Additionally, the stakeholders and scope of this project, as well as the initial questions and personal ambitions and objectives for tis project are layed out.

Context & Problem Definition

The moment a child learns to make their first steps independently also marks the moment that footwear becomes part of their daily life. Initially to protect the feet from the outside world, facilitating exploration and allowing the child to engage in new activities, outside of the house. Later, for many people, the aesthetic value and appearance of shoes becomes an increasingly important factor in the footwear selection process. Therefore, the design of footwear is concerned with creating products that not only fit the foot, but also the taste and style of the user. The current landscape of footwear consumption is characterized by a strong focus on creating product and brand associations that promote perceived value and status in the eyes of the consumer. Brands like Nike and Adidas create hundreds or thousands of different styles and colorways each year, and invest heavily in their marketing efforts to attract customers and keep them engaged. Product collaborations with high profile celebrities, tastemakers and drivers of culture influence the streetscape throughout the world.

Fit & Aesthetics

Unfortunately, our footwear habits do not always serve us well. When the time has come to select a new pair of shoes, often a compromise has to be made between the visual appearance of a shoe and the way it fits the feet. As preferences for certain shapes make its way into our collective taste, and the manufacturing of modern shoes relies on mass production, people are often confronted with the need to make a compromise between appearance and comfort. The result of this dilemma and the value of appearance in footwear was demonstrated to me during my work as a footwear retail assistant. People spend hours and multiple store visits to decide between a pair of shoes with superior comfort and fit, and a pair of shoes with a style and appearance that they consider more desirable. A consistent choice for aesthetics commonly manifested itself in the form of foot deformations and mobility problems in older customers, not uncommonly leading to a need for surgical corrections.

Children's Footwear

Many foot problems develop over time. Correct shoe fitting in children has, therefore, been noted to be very important. A correct fit would facilitate healthy development of maturing feet, creating a healthy support and base for life (Buldt & Menz, 2018; Klein et al., 2009; Mauch et al., 2008). The same dilemma between appearance and physical fit of the shoe to the feet of the user can also be found in footwear consumption in early ages. Previous research has identified visual appearance as an important factor in the decision making process for children's footwear. This is in part related to the value that footwear has in the social economies shaped by children and the desire to fit in with peers, but also due to the development of a sense of self and personal style as a child grows older (Pugh, 2009).

3D Printing

The inception of 3D printed footwear company Zellerfeld in 2020 reflects the developments and adoption of additive manufacturing within and outside of the product development phase. Various footwear designers and brands have dedicated themselves to exploring 3D printing as a new medium for the production of footwear for end-users (see figure 1). The application of 3D printed footwear creates new opportunities to seperate a product's appearance from its physical fit to the user's feet, as this technology can efficiently translate an individual's requirements into a personalized fit, tailoring the desired product into one that also fits the foot well. Continuing technological developments are making such a shift from mass-production to mass-customization increasingly feasible

Figure 1: 3D printed shoes produced by Zellerfeld © 2023 Zellerfeld

(Salles, 2011). The importance of this shift was underligned in personal conversations with an orthopedic footwear professional, who had spent years working in orthopedic footwear. Lacking adoption of technological innovation, decreasing amount of personnel and knowledge, and an increasing demand for orthopedic footwear, as a result of an increasingly old demographic, resulted in high pressure on her industry. Not only would efficient mass-customization be helpful in the fulfillment of orthopedic footwear, but it could also serve to decrease the amount of people requiring special orthopedic solutions as a result of wearing ill-fitting footwear.

Sustainability

A transition from mass-produced, traditionally manufactured footwear to mass-customization through the application of 3D printing does not only provide opportunities related to creating highly personalized products that promote healthy foot development. It can also help to accelerate the shift towards a circular footwear industry with respect for people and planet. As 22 billion pairs of shoes are dumped into landfill each year, on-demand manufacturing could help to counteract the industry's tendency to overproduce and dispose of products that have not seen a single day of wear (vivobarefoot, 2020). Furthermore, through the application of 3D printing, footwear can be created in a single part. Personal footwear disassembly experiments and existing studies show that many modern shoes consist of a complex assembly of up to sixty-five different parts, requiring three hundred and sixty assembly steps (Cheah et al., 2013). This product architecture makes it notoriously hard to process and capture some of the value of these products at end-of-life. Made possible through 3D printing, footwear from a single part, with varying structures and densities throughout to accommodate the various needs and functions built into a shoe, could radically reduce the complexity of the end-of-life process and allow us to capture the value of disposed footwear more effectively and efficiently. Business models should be designed in line with this new form of footwear, and take into account the value, impact and activities before, during and after product use.

This project zooms in on the user's needs and zooms out to consider the implications on the system that the user exists in. By oscillating between these two equally critical perspectives, this thesis aims to design a circular product-service system for 3D printed children's footwear. The goal of the system is to help parents and children to buy the footwear they want without compromising on the child's foot health and long-term mobility. Furthermore, this project focuses on gaining insights into current and future children's footwear consumption behavior and retail experience of the target group. Finally, it explores new customer segments and circular business models for 3D printed footwear.

Scope & Focus

The scope of this thesis includes children of up to twelve years old and their parents or legal guardians as decision-makers in the footwear consumption process. With regard to sustainability, this group has a challenge that is specific to this age range: children physically outgrow their shoes, creating a constant and rapid need for footwear replacement. This offers opportunities for the development of new design solutions and business models aligned with these challenges. Additionally, focusing on young consumers and their parents might offer possibilities to shape healthy and sustainable behavior around footwear consumption early on in the customers' footwear journey. The age cutoff of twelve years old was chosen as thirteen marks the beginning of teenage years, which generally represents a significant difference in physical and cognitive development.

The project aims to develop a strategic design solution that changes the interaction and relationship between end-users, children's footwear and foot health. As end-users of the developed concept, children up to twelve years old and their parents are important stakeholders in this thesis. Research is conducted with direct involvement of parents as end-users. The project is executed within the Faculty of Industrial Design Engineering at Delft University of Technology. The supervisory team and myself as project owner are directly involved throughout the entire project. Opportunities within this project lie in the possibility to get a better understanding of the psychological and physiological needs, as well as current and potential future consumer behavior and habits around children's footwear. Insights from this project could inspire footwear researchers, designers, brands and retailers to reconsider the concept of children's footwear and aid in a pursuit to create systems that harmoniously blend ergonomics and aesthetics with a long-term view on health. New ideas for circular business models in footwear could also benefit on-going research at the faculty of Industrial Design Engineering at TU Delft and its Circular Design Lab. Based on opportunities and touch points this project has with current industry developments, footwear manufacturers and research institutes specialized in digital fabrication, as well as footwear technology innovators specializing in advanced fit and sizing solutions could be considered indirect stakeholders in this project.

Initial Questions & Project Goals

By conducting research in children's footwear, the consumption thereof, and the application of 3D printing for footwear production, this thesis aims to create a concept design that could serve as a first step in the development and market strategy of a new product-service system that inspires and facilitates a shift towards a circular and inclusive footwear industry.

To further determine and specify the focus of this thesis, and to identify opportunity areas for design, questions were defined to guide the initial literature review:

1. How does aesthetic value influence the consumption of children's footwear?
2. How does footwear impact a child's foot development?
3. What believes do parents hold about the impact of footwear and fit on children's foot development?
4. How are parent and child involved in the selection process for children's footwear?
5. What challenges do children and parents experience with regards to finding well-fitting children's footwear?
6. What is well-fitting children's footwear?

Personal Ambitions

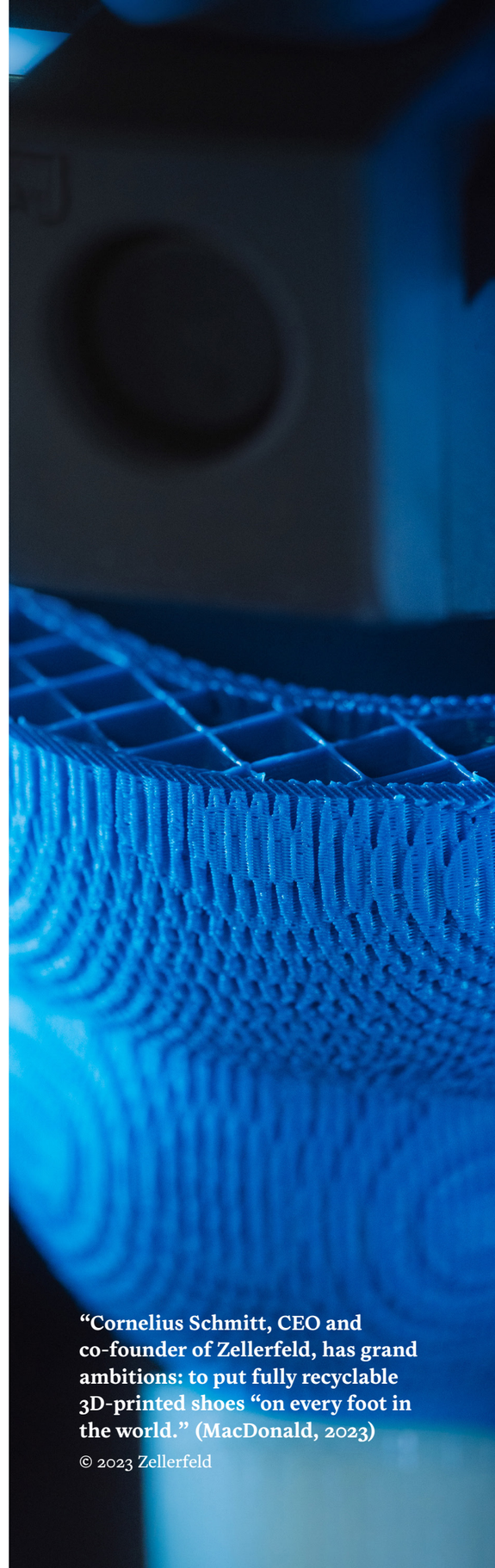
The following personal ambitions were formulated in addition to the overall goal of meeting all attainment levels for Strategic Product Design:

1. **Physical and/or digital prototyping.** During this project, I aim to create a variety of physical and/or digital prototypes for the product-service system that I develop, in order validate specific parts of the proposed design solution and turn ideas into tangible solutions that are easy to understand and communicate.

2. **Developing a faster and more iterative design process.** During this project, I aim to study and apply LEAN Startup methodology to quickly build prototypes, collect data on usage and effectiveness and analyze the data to know where and how to iterate on the proposed solution.

3. **Developing new skills around qualitative stakeholder research.** During this project, my goal is to actively seek and maintain good contact with relevant stakeholders and engage in in-depth interviews and user testing to iterate on the solution proposed in this project.

4. **Developing a greater understanding of behavioral science and possible design applications.** During this project, I seek to extend my theoretical knowledge on this topic through literature research. Additionally, I aim to apply this knowledge into the concepts that I design for this project.



"Cornelius Schmitt, CEO and co-founder of Zellerfeld, has grand ambitions: to put fully recyclable 3D-printed shoes "on every foot in the world." (MacDonald, 2023)

1.2 Project Approach

This section describes the approach of the project, and details the various tools and methodologies that were used to guide the research and concept design process in this project. A visual overview was created to outline the project activities, project structure and report structure in figure 2.

Approach & Methodology

Vision in Product Design (ViP)

Various methods and approaches were applied in this thesis to guide and support research and design activities. At the heart of this project lies the Vision in Product Design method (ViP). Context- and interaction-driven design was used to drive forward a future vision, resulting in meaningful solutions for end-users and the wider system they are part of. Following the concept of the ViP design method, this project starts with the deconstruction and analysis of current children's footwear, consumer behavior and retail experiences, before engaging in the design of a new system for children's footwear. As this thesis takes on a somewhat entrepreneurial approach without direct collaboration with existing companies, the resulting concept design strongly reflects the personality and vision of the designer, myself. This vision has been partially crafted over the past few years through research on the topics of footwear innovation and sustainability, and has been further explored and refined during this thesis, in alignment with the specific challenge and target group.

Circular Design

The Circular Economy framework by the Ellen MacArthur Foundation (2013), the principles lined out in Donut Economy by Kate Raworth (2017) and insights from previous personal explorations in the field of circular design for footwear are used to inform the design of a circular PSS in this thesis. The proposed concept goes beyond the use phase, and considers both the production and the end-of-life stage for the physical product that is part of the system.

Strategic Design

In alignment with the Master's program that this thesis is part of, Strategic Design is reflected in the formulation of an innovation vision, and the identification of business opportunities related to this vision (Calabretta et al., 2016). By use of tools, methods and principles, strategic decision-making is influenced, and opportunities are selected based on a balanced consideration of the extent to which the opportunity fits the needs and wishes of people, as well as the goals and assets of the designer or envisioned company.

Interaction & Integrated Product Design

While the foundation of this thesis is built on the Strategic Design principles that are part of the Strategic Product Design Master's program, the activities in this project extended into interaction and embodiment design. A highly human- and interaction-centered approach is reflected in this thesis by the involvement of end-users throughout the research and design process. Through both formal interviews, and more casual and continuous engagement and interaction with the target group, rich data about user needs, challenges and desires were captured. Literature research, covering different aspects of consumer behavior, further drove forward the concept design for future interactions. Finally, previous experience with the target group in a footwear retail context was used to both formulate the initial research question, and guide the design process to create a solution that is aligned with various stakeholders in a real life setting.

Previous projects and personal endeavours have resulted in topic specific knowledge and skills that were used and expanded on for the creation of working prototypes in this thesis. This includes knowledge about the product architecture and manufacturing methods for footwear, an understanding of footwear design and aesthetics, and some experience in the creation of 3D models and physical prototypes through 3D printing.

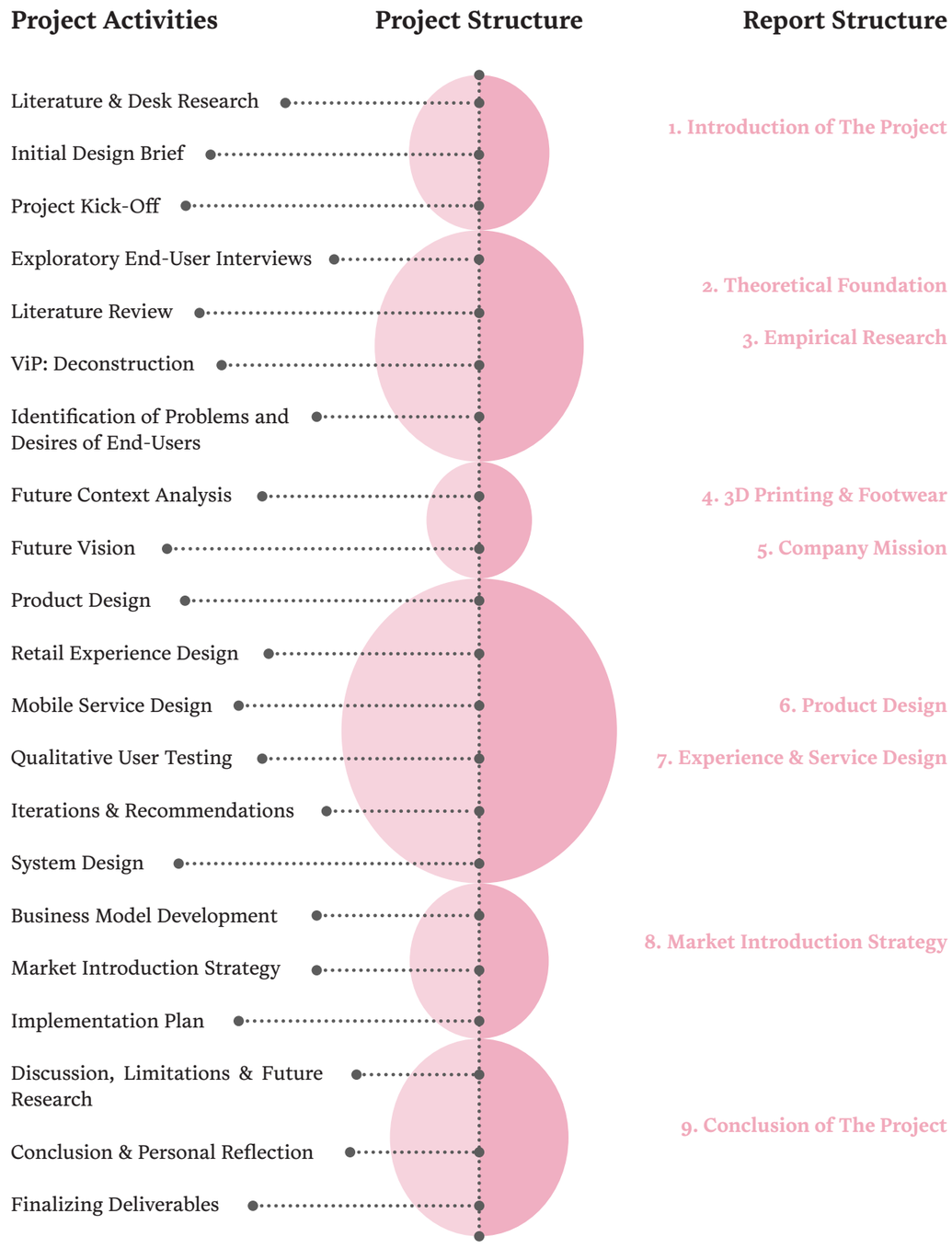


Figure 2: Overview of project activities, project structure and report structure

02

Theoretical Foundation

This chapter contains a summary of the theoretical foundation of this thesis, consisting of three parts: 1) Identity and Social Value of Children's Footwear, 2) Physical Function of Children's Footwear, and 3) A Conceptual Framework for Fit.

The first section discusses the symbolic value of children's footwear in relation to visual appearance, from both a parent's and a child's perspective. The second section discusses the physical impact of footwear on children's feet and parental attitudes towards this. Finally, the third section concludes with a conceptual framework of fit, based on the previous two sections. This framework forms a starting point for the concept design in this thesis.

2.1 Identity and Social Value of Children's Footwear

Aesthetic Value of Footwear
Consumption in Parenthood
The Importance of Fitting In
Self Sacrifice & Authentication
Form Over Function

2.2 Physical Function of Children's Footwear

The Importance of Well-Fitting Footwear
Finding The Correct Size
Attitudes Towards Children's Foot Health
Sources of Footwear & Foot Health Information
Uncertainty Around The Impact of Footwear

2.3 A Conceptual Framework for Fit

Three Forms of Fit
Interaction Between Footwear Functions
Balancing Fit in Co-Consumption

Key Takeaways & Design Considerations

2.1 Identity and Social Value of Children's Footwear

This section discusses the aesthetic and symbolic value of footwear for parents and children. It summarizes the sociocultural aspects of footwear, and explores how children's footwear is used for self-authentication and group signalling purposes.

Aesthetic Value of Footwear

The design of modern footwear is dictated by a combination of form, fit and function. Hereby, form is related to the aesthetic appeal of footwear, whereas fit relates to how footwear can accommodate the morphology of the foot, and function pertains to the ability of footwear to accomplish a specific intended purpose, such as protecting the foot of an individual during activity (Buldt & Menz, 2018). The aesthetics and visual appearance are an important determinant of people's footwear buying decisions (Au & Goonetilleke, 2007). The form of modern footwear is heavily dictated by popular culture (Cheng & Perng, 2000), and the importance of aesthetics can be found in relation to coveted footwear, demonstrating the value of shoes as status symbols (Skidmore et al., 2023). Footwear's relationship with pop culture can quickly be found in the modern day craze around sneakers, as well as the communities and subculture that have grown around it. 90's pop culture has been instrumental in turning footwear from a functional product into something aspirational. Athletic shoes where able bridge the gap between athletic wear and lifestyle, and they became symbols that could establish and communicate your membership or affinity with a certain community (Matthews et al., 2021). The value of shoes in communicating status, public image and personal characteristics, as well as stereotypes, can also be found in research showing that people can generally pick up on the image a shoe wearer is conveying, and that shoes can be a reliable source of information (Gillath et al., 2012). The shape of shoes, such as pointy toes and high heels, are also used to identify and communicate the sex and attractiveness of people (Morris et al., 2013), and can play a role in the manifestation of maturity (Hao, 2021). The value of shoes in communicating status and personal characteristics is not limited to modern footwear or adult footwear. As footwear has a direct connection with human culture, from the aspect of fashion, and one can express oneself or distinguish oneself from others, it is vital for archaeology (Sarv, 2006). Besides adult footwear, children's footwear also played an important role in the Roman Empire to signal status and establish one's role as a valued member of society at a young age (Collins & McIntosh, 2014).

Consumption in Parenthood

Social group signaling related to footwear can also be found in the transition of women into motherhood. Where women want to visually appear as people who take good care of their children, and possessions are intrinsically loaded with both private and public meaning, infant clothing can be seen as symbolic of skills of the individual in the mothering role (Åberg & Huvila, 2019; McNeill & Graham, 2014). Parents are conscious about the fashion choices they make for their children and sending the right message to others. It was found that branded footwear carries considerable local exchange value and most parents feel the need to conform to locally accepted styles of dressing their children (Ponsford, 2014). Similar to how people were shown to be able to identify personal characteristics of others through the footwear they wear, mothers were shown to use clothing of their children to socially position themselves and other mothers, and make conclusions about people's character. Additionally, it was noted that parents are trying to find a balance in consumption behavior around their children to prevent being perceived as overly invested in the appearance of their children (Åberg & Huvila, 2019). Fitting in, rather than impressing others, was previously identified as an important driver of consumption behavior for mothers (McNeill & Graham, 2014). Previous literature claims that children can be seen as part of their parent's appearance. Moreover, children are often seen by parents as an extension of themselves, someone who represents them, and they are dressed accordingly. The child as extended self allows parents, and especially new mothers, to construct a new self-identity that is related to their new role and life phase (Åberg & Huvila, 2019; McNeill & Graham, 2014).

The Importance of Fitting In

The consumption of children's footwear is not only related to the desire of parents to fit in with their reference group, but also to the desire of children to fit in with their peers. Teens and adolescents have previously been shown to attach significant social status to the footwear they wear, and it was found that fitting in with peers, for children across different age groups, had significant effects on their psychosocial wellbeing and development (Driano et al., 1998; Sweet, 2010). Footwear was found to hold significant value in the economies that are shaped by children together, which determine children's sense of value and belonging. Parents, in turn, are willing to invest a significant amount of resources to ensure that their children will not feel different from other children, often against a parent's better judgement (Pugh, 2009). Previous research states that girls in particular might be influenced by peers in their choice, to avoid humiliation, and to enhance affiliation and belonging. On the other hand, boys were found to attach above average value to specific brands, as they saw those as being vital to their sense of belonging to a group and used it as a device to communicate messages to their peers (Tongue et al., 2010).

Self Sacrifice and Authentication

In order for parents and their children to fit in with their peers, new parents often see a radical shift in their consumption patterns. Shopping for themselves becomes a less frequent activity, personal consumer desires are abandoned, and mothers especially consciously put aside their own needs and wants to provide for their infants. Even though this change in spending often means a financial sacrifice, parents have also reported that it can provide feelings of satisfaction and pride, as parental sacrifice seems to be an indication of being a good parent (McNeill & Graham, 2014; Ponsford, 2014). This aligns with literature that has previously stated that people have turned to the marketplace and use brands and consumption rituals as resources for self-authenticating purposes (Beverland, 2021). In parts of the world, the amount of money being spent on children's clothing has been rising over the past decades and marketers have previously dubbed the children's market "bulletproof" and practically impervious to economic dislocations, due to the parent's pride that prevents them from cutting back significantly on children's expenses (Pugh, 2009).

Form Over Function

Even though aesthetics and cultural associations are important drivers of both adult and children's footwear consumption, these are not the only factors that shape the consumption and use of footwear, as new shoes should also satisfy the biomechanical requirements of the foot shape (Cheng & Perng, 2000). The fact that these requirements for footwear do not always align with each other, can be seen in the use of footwear and traditions that do not benefit healthy foot development and constrain lifelong mobility of individuals (Hao, 2021). This conflict between fashion and function might also be visible on a product level, when we look at the considerations that go into the design of a shoe last, the basis of most footwear design. Previous research states: "When designing a shoe last, no matter how drastically the style of the forepart of the shoe last is changed, the back part of a shoe last almost remains the same. In general, the back part of a shoe last is entitled to functional design whereas the fore part fashion design" (Cheng & Perng, 2000). Literature has also stated before that manufacturers have the challenge of combining orthopedic needs with consumer demand to produce a marketable shoe, rather than a perfect shoe ('Foot Health in Children', 1965). Research suggests that for children, the influence of aesthetics and economics, rather than considerations of health, is problematic as the correct choice of footwear is especially important because their growth and development are characterized by the evolutionary dynamics of the locomotor system and by the physical activity to which the lower body is subjected (Medina-Alcantara et al., 2019).

2.2 Physical Function of Children's Footwear

This section discusses the physical impact of footwear on children. A summary of existing literature about the importance of, and challenges around, well-fitting children's footwear is provided, and current gaps and conflicts in literature are discussed.

The Importance of Well-Fitting Footwear

Foot problems might be one of the most frequent reasons for people to seek consultations at primary care units, and many of these conditions can generate problems with balance and gait, increase the risk of falls, and decrease the ability to undertake activities of daily living (López-López et al., 2018). The shoes we wear can have a significant impact on our foot development, foot health and lifelong mobility. Previous research has shown that a variety of these foot health problems are directly related to the use of ill-fitting footwear. Pain and deformations can be the result of wearing footwear with insufficient length. Hallux Valgus, for instance, is a foot deformity that has been researched especially well in relation to footwear, and it has been repeatedly suggested that this condition often finds its origin in the shape and size of the shoes we wear (Buldt & Menz, 2018; Cheng & Perng, 2000; Klein et al., 2009). Foot problems like Hallux Valgus can give serious complications for people over time, decrease quality of life and possibly require surgical intervention (López-López et al., 2018). Additionally, such deformations can significantly affect shoe fit as well and prevent people from wearing the shoes they want to wear (Cheng & Perng, 2000). As footwear related foot problems often develop over time, it has been claimed that correct shoe fitting in children is of paramount importance to ensure normal development of maturing feet and create a healthy base of support for life (Buldt & Menz, 2018; Klein et al., 2009; Mauch et al., 2008). Attention should be paid to ensure that children are neither wearing shoes that are too narrow or too short, as this may squash the toes together. It is suggested that prevention and early diagnosis of foot problems leads to easier correction, as children's feet are different from adult feet, in that they are more malleable, react more sensitively to external factors such as shoes, they are constantly changing as a child grows and still solidifying in structure and form (Buldt & Menz, 2018; Cheng & Perng, 2000; Medina-Alcantara et al., 2019). Finally, having correctly fitting shoes is essential for children to make optimal use of the footwear they have and for footwear to optimally fulfill its functions, as fit governs function and the intended purpose cannot be fulfilled if footwear does not fit the foot correctly (Buldt & Menz, 2018).

Finding The Correct Size

Finding the correct size is not easy for parents and their children. Parents are experiencing difficulties due to inconsistencies in how shoe shops measure children's feet, limited options to have children's feet measured, different sizing systems, a lack of companies offering fitting advice, and varying availability of styles and fit of shoes. It was also stated that parents have reported difficulties in finding suitable footwear that accommodates their child's foot shape (e.g. flat, wide or narrow feet) (Hodgson et al., 2020, 2021). Cheng & Perng (2000) stated that foot length is virtually used as the basic measurement in nearly all shoe size systems. However, different size specification systems exist throughout the world (see figure 3), to accommodate for the different foot shapes due to differences in gender, age, race and habits of living. An individual's foot shape can even differ significantly based the time of day. Even though these sizing systems exist, most footwear brands will only create one type of shoe last that is changed to accommodate for different sizes, but it generally does not take the significant intercontinental differences in children's foot morphology into consideration, which are the result of different racial and environmental factors (Mauch et al., 2008). Currently, the challenges that parents experience are reflected in the amount of returns and customer dissatisfaction that is generated as a result of incorrect sizing, as well as in the amount of children that are wearing the wrong size shoes (Tongue et al., 2010). A

US	EU	UK	Canadian	Japanese	Inches	CM
4.5	20	3.5	4.5	12	4 5/8	11.7
5	20	4	5	12.5	4 3/4	12.1
5.5	21	4.5	5.5	13	5	12.7
6	22	5	6	13.5	5 1/8	13
6.5	22	5.5	6.5	14	5 1/4	13.3

Figure 3: Children's footwear sizes based on different sizing systems (Nordstrom, n.d.)

study by Klein et al. (2009), underlined the importance of providing parents and the general public with comprehensive information on the importance of properly fitting shoes and the criteria of a proper fit, as they had found that 69,4% of examined children wore outdoor shoes of insufficient length. The same was true for 88,8% of the indoor shoes worn by children. The problem of ill-fitting footwear extends from childhood into adulthood, as several studies have reported similar numbers for adults and elderly with regards to the use of ill-fitting footwear (Buldt & Menz, 2018; O'Rourke et al., 2020). The proper selection of footwear is essential to reduce foot problems (Cheng & Perng, 2000). Therefore, more awareness and education is needed around foot size and the correct fit of footwear, and, at the same time, footwear manufacturers should produce footwear that better accommodates the variations in size, shape and general foot morphology among the population. A straight forward way would be for manufacturers to start producing footwear in more diverse widths, alongside a large selection of length sizes (Buldt & Menz, 2018; Tongue et al., 2010). It should, however, be noted that what constitutes an objectively correct fit is not always clear, and perceived comfort can be related to tactile, auditory and olfactory sensations. Furthermore, fit and perceived comfort can change significantly over time, and depend on time of day, activity performed and a person's health status (Au & Goonetilleke, 2007).

Attitudes Towards Children's Foot Health

To further understand the high frequency of ill-fitting footwear in children, and infrastructure that facilitates poor footwear choices with regards to fit and foot health, we might look towards the attitudes of parents, as well as footwear and health professionals, towards footwear and foot health. Previous research has found that parents will generally recognize the potential impact foot care could have on their children's overall health and wellbeing, and they would generally observe their children's feet to ensure healthy foot growth. However, it was also found that parents would often be unsure about their beliefs around children's

foot health, and the assessment of healthy foot development would be a subconscious process of checking for any abnormalities or pains in the child's feet and their ability to move. Studies also suggested that foot health is generally not considered an important health concern and is often of low priority to parents, compared to other concerns (Hodgson et al., 2020, 2021). Babies and children were, however, celebrated for being comfortable with their feet and being more barefoot, whereas adults often had a more negative relationship with their own feet, as a result of the same struggle that could be found in footwear: combining beauty with function and strength. Negative expressions about the appearance of the ageing foot further suggested the relevance of aesthetics in relation to feet (Skidmore et al., 2023).

Sources of Footwear and Foot Health Information

Previous research into the decision-making process of parents around footwear and foot health has revealed several sources of information and challenges that are involved in the footwear consumption of parents and their children. In their search for well-fitting footwear, parents were shown to be guided by leading footwear companies, due to their long-standing market presence and widespread brand familiarity. Even though it was stated that children's feet are not a frequent topic of discussion among parents, parents have repeatedly identified the opinion of other parents as another important source of information to guide their foot health and footwear decision. Parents with more and/or older children are often seen as a reliable source of information, drawing information from their own experiences or information received from family members (Hodgson et al., 2020). In fact, findings suggested that familiar voices were actually favored over a professional one with most parents not visiting orthopedic specialists, and mediating information from specialists with personal experiences and information provided by other parents. In addition, parents have previously claimed that they were or that they felt encouraged to inform themselves with regards to foot health information before and after visiting a health professional . Many parents were found to use a variety of online sources to learn more about footwear, foot health and to seek advice and information related to diagnosing and treating children's health conditions in general (Hodgson et al., 2021). Websites, parent forms and social platforms like Twitter and Facebook might be highly important in the way modern parents access health information. However, parents also stated that it can be hard to figure out what to look for and which sources to trust. Skidmore et al. (2023) stated: "There was confusion about how best to care for feet such as when to put a child in a first pair of shoes, 'normal' childhood foot development, how to treat common pathologies, and caring for the foot at risk. Mistrust also featured in relation to commercial entities such as children's footwear providers, inconsistent foot measuring and the practical utility of the advice given by some foot health professionals". Furthermore, it was stated by Hodgson et al. (2021) that footwear is a topic that raises anxiety for parents with regard to determining the type of shoes that should be worn, when the child should start wearing shoes, whether a professional should be engaged in shoe fitting, and how much time children are supposed to spend wearing shoes.

Uncertainty Around The Impact of Footwear

Unclarity and confusion around the role of footwear, proper fit and foot health might not only be the result of a lack of awareness or parents not knowing what to look for. There is another problem that might consciously or subconsciously have shaped footwear care habits for both adults and children. An ongoing debate between two fields of research has shaped a footwear landscape full of conflicting information and arguments that have led to contradictory advice and footwear options that strive to achieve similar goals in opposite ways. Traditionally, the field of orthotics has been instrumental in the development of foot treatment through footwear inserts, and the selection of healthy footwear that helps the foot to develop correctly. However, the barefoot school of thought has been diametrically opposed to such practices, offering highly flexible footwear with a wide toebox and thin sole (see figure 4), as it is suggested that specialized footwear, inserts and footwear in general is detrimental to

Figure 4: Barefoot style children's footwear by Vivobarefoot (Nelson, 2018)

healthy foot development and lifelong mobility. A variety of studies has discussed the potential link between certain types of footwear and the development of different foot problems, such as Hallux Valgus (a deformation of the toes) and Pes Planus (flat feet), as well as the potential impact of footwear on gait, foot shape, muscle development and foot strength (Buldt & Menz, 2018; Cheng & Perng, 2000; 'Foot Health in Children', 1965; Hollander et al., 2017; Joshua et al., 2011; Klein et al., 2009; Wolf et al., 2008).

On the other hand, Hollander et al. (2017) stated that despite the increasing interest in barefoot walking, the evidence for long-term effects on foot characteristics is small, and that the use of footwear may actually play an important role in childhood foot development by being beneficial for the development of the foot arch. When assessing the available literature on this topic, it can be concluded that there is a general indication that the size and shape of footwear have an impact on the development of children's feet. However, future research is needed to determine the impact of footwear on foot development and mobility, as previous studies have found conflicting results with regards to the specific effects of footwear on foot development and pathologies. Additionally, the effect of footwear on a child's gait, strike pattern and motor skills, as well as possibly related footwear characteristics, such as flexibility and weight, are stated to require more in-depth research, as the field of biomechanics is still developing (Joshua et al., 2011).

Finally, with regards to the selection of footwear to benefit a child's development, both parents and orthopedic specialists should be aware of the possible psychosocial consequences that might come with their choice for certain children's footwear. As stated previously, footwear was found to hold significant value in the economies that are shaped by children together, which determine children's sense of value and belonging and peer perception (Pugh, 2009; Sweet, 2010). Not being able to fit in with their peers due to the use of corrective footwear during childhood, was found to have significant negative effects on adult self-esteem and it was found that people can often have vivid recollections of wearing modified shoes as a negative experience. It was also stated that some physicians had considered corrective shoes or inserts as harmless placebo's for conditions that would have naturally resolved itself anyways, and they had only prescribed such products under pressure from parents who wished to be offered treatment for their child (Driano et al., 1998).

2.3 A Conceptual Framework for Fit

This section details the creation of a conceptual framework of fit. This framework is largely based on conceptual insights from previous sections and provides a basis for concept development.

Three Forms of Fit

Based on the information presented in previous two sections, I conclude that finding a pair of fitting children's shoes relies on three needs that parents and children take into consideration, consciously or unconsciously and to varying degrees, when deciding which shoes they want to buy and wear.

First is the need for physical protection and support. Appropriate footwear allows a child to engage in physical activities. Physical activity is important for a child's physical development and it allows a child to feel comfortable and confident in their own body and their capabilities (Tremblay et al., 2000). Second is the need of a child to create their own identity. Developing a sense of self, and aligning that with the things they wear is increasingly important as a child grows up (Readdick et al., 1996). Shoes allow children to communicate and express who they are to the outside world. Third is the need to fit in. Fitting in with the prevailing norms of the group is needed to gain a sense of belonging. Knowing what is cool and seeking approval from peers is important for most children, as they try to find their place in a social group. It directly affects the types of shoes they want to wear and the associations they want to avoid, as shoes are a particularly visible means of consumption (Marshall, 2010; Price et al., 2021).

Based on these three needs, it could be said that there are three types of fit that are important for children's footwear (see figure 5): physical fit, identity fit and social fit. The physical fit is dictated by the physical shape of the shoe and how it behaves under pressure and movement of the body. When footwear was invented thousands of years ago, its main function was to protect the foot from the environment it was in (Hamill, 2013). This is still an important function of modern footwear, and is increasingly accompanied by a design that aims to support the foot through various activities and movements. The identity fit is related to the role of footwear in a child's development of self. Clothing is not only being worn, it is rather a tangible material posession connected directly to the body, inevitably becoming a part of a child's construction of a sense of self (Readdick et al., 1996). Social fit is related to the role of footwear in the psychological and emotional protection and support of an individual in a social context. Fitting in with the peer group is of great importance for many young consumers and shoes are used to symbolize the link between the individual and the group they wish to be accepted by. Therefore, shoes are physical objects that can function as psychological shields for children, to protect them from being teased, bullied or excluded from the group they want to be part of (Marshall, 2010).

Figure 5: Three forms of fit

Interaction Between Footwear Functions

In addition to the values that are represented by each individual circle in this model, there are various relationships to be found between the physical, social and identity functions of children's footwear. First of all, a confluence of the physical and the social function of footwear is demonstrated by the fact that not owning the correct footwear can make it hard for children to join certain activities, increasing the chance of being or feeling excluded from the group. Additionally, social pressure might cause someone to choose a pair of shoes that has a poor physical fit, as result of the desire to conform to the group. Between the physical and the identity functions, a similar compromise can be found, as physical properties of footwear, such as fit and comfort, are weighed against the desirability of the symbolic and aesthetic value tied to the shoe. Psychological comfort is weighed against physical comfort, and in many cases compromises are made. From my personal experience working in a children's footwear store, high identity and social fit of a shoe can often lead to children assessing the physical fit of a shoe more positively, and ignoring certain physical fit problems. This finding aligns itself with Marshall (2010), stating that certain people will judge a product's functional features based on the product's symbolic value and brand image, as well as research by Price et al. (2021), that found a direct compromise of physical fit for aesthetics by children with regards to footwear. Driano et al. (1998) further highlight the importance of balancing the immediate physical fit with social fit, as it was found that special orthopedic footwear in childhood can have significant negative psychosocial effects on children that last far into adult life, affecting the confidence and self-perception of people. At the confluence of the social and identity functions, the costs and benefits of either conforming to social norms and belonging, or expressing individuality and rebellion are weighed against each other. However, the development of a personal identity and expression thereof can also allow children to find others like them, allowing for new and powerful social connections.

Balancing Fit in Co-Consumption

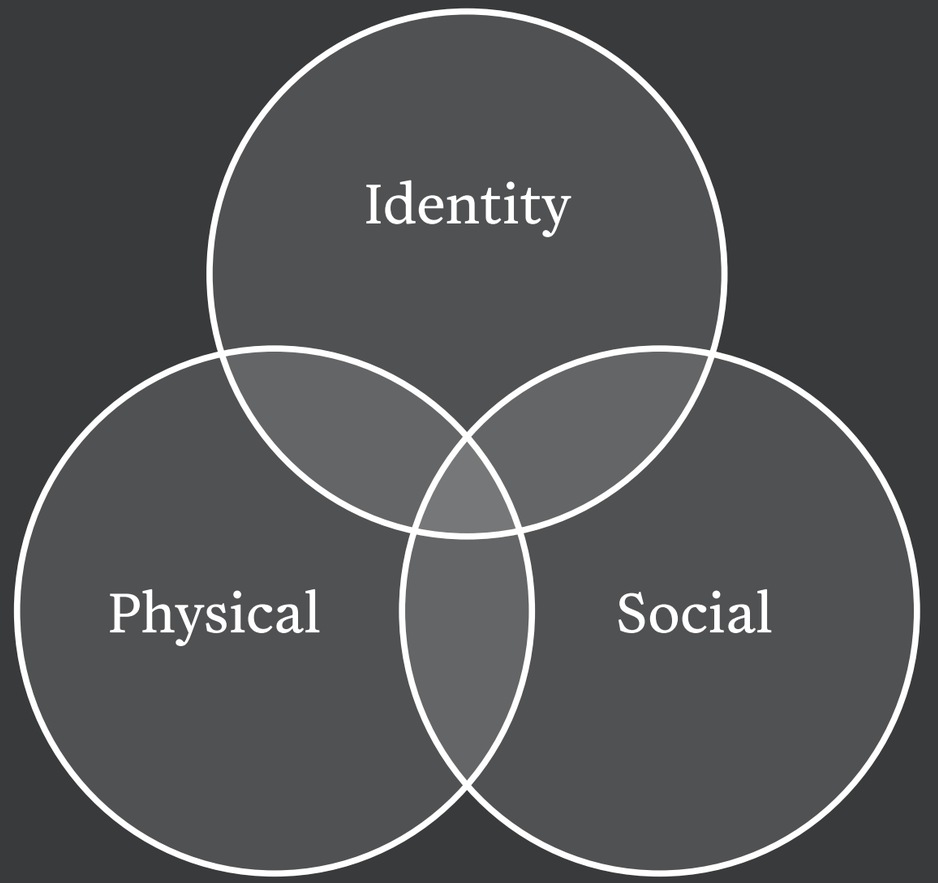
The child is not the only decision-maker in this process. Apart from the financial reliance of the child on its parents, parents play an important role in shaping the consumption behavior of their child from an early age (Price et al., 2021). Parents are balancing their own desires for themselves and for their child with the direct desires of the child. Furthermore, the parent's form of consumption partially determines the child's desires and preferences that they will be able to satisfy with their future purchasing power (Raworth, 2017). On the other hand, previous research also suggests that children assume an authority to modernise parents' tastes, influencing parents to consume as urged by their children (Marshall, 2010)

Price et al. (2021) found that development of the child's independence and autonomy with regards to footwear selection is considered important by parents. However, based on previously stated findings that the child is often perceived as part of the parent's sense of self and social identity (see chapter 2.1), tensions might arise from the independence of growing children with regards to footwear choices. Additionally, some parents might fear that increased independence could result in short-term increased risk related to the health and safety of the child, as well as the social acceptance of the child among peers (Bristow, 2014; Crawford, 2015; McCready, 2021; Price et al., 2021).

Exploratory research in the form of semi-structured interviews with parents of children up to twelve years old was conducted in this thesis, and is described in the following chapter. One of the topics of conversation was the role of parent and child in the footwear selection process, and the effect of offline and online shopping behavior, as well as age and gender, on the dynamics of co-consumption. These insights were used for the design of a new product-service system for children's footwear that respects the parent-child dynamics of co-consumption and find ways to make it easier for both parent and child to fulfill their needs related to footwear, while being mindful of how these changes might affect other values that footwear choice is based on.

Key Takeaways & Design Considerations

- For the design of a new system for healthy children's footwear, neither a barefoot, nor an orthotics approach should be assumed. Rather the system should be designed to provide new insights and teach us more about the impact of children's footwear on foot development over time.
- The design of the system should allow users to make decisions around children's footwear with confidence.
- Design for inclusivity and fitting in is preferred over exclusivity and standing out, amongst parents and children.
- The children's footwear market is considered strong, due to parents' willingness to self-sacrifice and tendency to derive fulfillment out of their redirection of resources to their child.
- A new system for children's footwear could help first-time parents with transitioning into their new role as parent, and take away their insecurities and anxieties around providing their child with appropriate footwear.
- The new system should enable children and their parents to make footwear decisions without a need to compromise foot health or aesthetics, by providing footwear solutions that balance function and aesthetics, perfection and marketability.
- The system should provide products with correct sizing, as correct shoe fitting in children is of paramount importance to ensure normal development of maturing feet and create a healthy base of support for life.
- The system should reduce the amount of children wearing footwear of insufficient length.
- The design of a new system for healthy children's footwear should consider the parent's preference for a familiar voice over a professional one with regards to footwear.
- Exploratory end-user research is necessary to further understand how modern parents access foot health and footwear information, as well as their preferred modes of footwear consumption, and the role the parent and the child play in the footwear selection process.
- Furthermore, end-user research is necessary to address the challenges that parents and children experience with regards to buying and using children's footwear, as well as current practices around the end-of-life of children's footwear.



Three forms of fit that make up a personal fit in footwear: Identity Fit, Social Fit & Physical Fit

03

Empirical Research

This chapter describes the empirical research that was performed as part of the exploratory phase of this thesis. Through qualitative research with end-users, current consumption behavior around children's footwear is uncovered, and challenges and desires throughout the various phases of footwear consumption are explored and defined. The insights of this study were eventually combined with insights presented in chapter 2, as well as existing insights as a result of the researcher's personal experience working in retail of children's footwear. Based on this information, a visual overview was created, presenting challenges and desires of parents and children throughout six different phases of the consumption cycle of children's footwear. These insights create a basis for the product-service system developed in this thesis.

3.1 Exploratory Research

Research Method
Results
Discussion

Key Takeaways & Design Considerations

3.2 Mapping The Customer Journey

3.1 Exploratory Research

This section includes an overview of the method that was used for the exploratory research with end-users, as well as the research questions that were used to guide this study. Furthermore, this section provides an overview and explanation of the results this study has produced.

Introduction

As concluded from the literature review, topics that will be further investigated in this chapter include the customer journey, challenges and desires around children's footwear shopping and use, current practices around finding a good fit, modes of children's footwear consumption, and the role of parent and child in the selection process. Furthermore, this study aims to gain an in-depth understanding of current practices around the end-of-life of children's footwear. In this way, the study aims to further deconstruct the current product and service experience around children's footwear. Following the steps of the ViP design method, this deconstruction phase forms the main input for the design phase of this thesis. For the purpose of this study, the following research questions were formulated:

RQ1: What challenges and objectives do parents currently have with regard to their consumption of children's footwear?

RQ2: What is the role of parent and child in the selection process for children's footwear?

RQ3: What modes of footwear consumption and information sourcing are used by parents and children?

RQ4: How do parents deal with the need to weigh the aesthetic and functional value of children's footwear when selecting a new pair of shoes?

RQ5: What practices do currently exist amongst children and parents around the end-of-life of children's footwear?

Research Method

Research Design

In order to collect rich data that could inform the design of a new product-service system, semi-structured qualitative interviews were conducted with possible end-users. This particular interview structure was chosen as it allowed for a flexible and exploratory approach, with the possibility for the researcher and participant to further elaborate on topics that might arise during the interview and are considered of interest to the study. An initial interview guide for this research was created, based on existing literature, as well as personal observations from my own time as a children's footwear retail assistant. The goal of the formulated quesions was to test certain assumptions and theoretical insights early on in the project and identify possible knowledge gaps and areas of interest that could further inform the design process. For this study, a pilot was first performed with three parents. All three parents fell into the target group of having one or more children up to twelve years old. The duration of these conversations was between thirty and ninety minutes. Based on this pilot study, the interview guide was further developed. Insights from these conversations were captured in the form of written notes and were also included in the final customer journey map. Even though these early conversations provided valuable data for this project, it is important to note that these shall be considered as informal conversations, and no direct quotes have been derived from these conversations. After this pilot, four formal interviews were conducted, each with a duration of thirty to ninety minutes, and with a parent of at least one child of up to twelve years old. Every interview was recorded on a dedicated audio recording device, manually transcribed and analysed in order to identify common themes. The interview guide was not modified between these interviews (see appendix B). The general outline of the interview guide used in these interviews is as follows: After confirming the gender and age of the child(ren) of the particpant, introductory questions are asked about the participant's general relationship with the consumption of children's footwear. Secondly, the participant is asked to reflect on their own previous experiences with buying children's footwear in a physical store and/or online, based on the method(s) they use. Thirdly, the participant is asked about possible struggles related to finding children's footwear that fits well and looks good. Afterwards, the participant is asked to briefly reflect on their practices around used footwear, as well as their behavior and perceptions around the use of second-hand children's footwear. Finally, the participant is asked about the role that their child plays in the process of selecting a pair of shoes, and participants are asked to describe what an ideal shopping experience for childen's footwear would look like for them. Three out of four recorded interviews were conducted in dutch, while one was conducted in english. For readability purposes, dutch quotes in the results section are translated from dutch to english by the corresponding researcher and using free online available translation tools.

Sampling & Communication

Participants were found through the personal network of the corresponding researcher and through snowball sampling. All participants in the pilot and the main study were female. This was not intentional, but rather a likely consequence of the request to speak to the parent most responsible for the consumption of children's footwear in the family. Five out of seven participants were of Dutch Nationality and living in the Netherlands at the time of this study. One participant is of American Nationality and living in the US, and one participant was living on Curaçao. Even though the number of participants for this study was limited, the representation of international perspectives is considered desirable for this study, as it might give initial insights into foreign perspectives on the topic. Such perspectives can lead to a broadened perspective on children's footwear, possible differences in behavior and attitude that might be important for the design of a new product-service system and selecting a market. All participants were directly contacted through WhatsApp and Instagram. Further correspondance was done through email, in addition to the previously stated communication channels. Except for one informal conersation that was conducted on location, all conversations and interviews were conducted through Zoom

Results

Written notes of the informal conversations and transcriptions of the formal interviews were analysed and common themes were identified.

Identity and Social Fit

Parents acknowledge the importance of providing their child with shoes that allow them to fit in with their peers, and also see shoes as a medium of self-expression and taste development. A lack of suitable style options with a good physical fit is experienced as a limitation.

"Kids don't like to stand out unless it's something that they feel like is really popular." - p1

"But at school, classmates do look like 'oh, what do you have, what do you have?' Fortunately, [my daughter] is quite unique and creative, and has her own taste, regardless of what others have or don't have." - p2

The Role of Choice

Parents value having access to a good amount of footwear options to choose from when it comes to style and color. This is an important driver for the shift to mainly online consumption of children's footwear, as noted by most parents.

"Yeah, it was so little choice and so boring! I thought, you know online I've found nicer ones for [my oldest daughter] ... Online you see so many cute little models." - p3

"But we have often bought online because we also liked the aesthetics. Not from the beginning, but when she was towards three years old, then we liked to buy some nice looking shoes. And then we bought them online." - p4

However, an excess of choice and no clear selection criteria and tools can turn the availability of options into a negative.

"I think the amount of choices are actually the problem. There is too many choices ... there is just so much that going online is the better option. But even still there is too many choices, it's kind of overwhelming." - p1

Differences in Sizing Systems

Differences in fit between different footwear brands and styles are experienced as highly incovenient and is an important factor that drives parents' choices for certain styles, brands and methods of buying children's footwear.

"Because the [size] twenty that [my youngest daughter] has from a baby store is not the twenty from yesterday's store. It's two sizes bigger, this size twenty. So you can't buy online." - p3

"If you look at American clothes and shoes, our numbering system is not consistent. People like to try shoes on, period. But with kid's shoes it's even worse. It's frustrating." - p1

Importance of Footwear for Foot Health

The impact of footwear on children's foot development is understood by parents to varying degrees, but all parents agree that choosing the right footwear is important for their child's foot health, and even beyond the foot alone.

"If you don't have the right shoes, then very quickly you can have problems with your body, your back, your pelvis, your legs, even your feet, your ankles and also deformities in the feet you know." - p3

"So a shoe with good cushioning, a good sole, that she does walk well, also for her back of course and for health. So we do look at that rather than just the beauty. Of course, it also has to have some good orthopedic support for her foot." - p2

However, none of the parents that were interviewed felt particularly confident about the actual impact of footwear on their child's foot health. Conflicting information from different sources around different approaches to footwear and foot health make it hard for parents to understand what is best. Foot health was also not considered a common topic of discussion among parents. A lack of awareness and available information was also noted as an important factor.

"It doesn't come up a lot in conversation but here and there you hear about that the shoes without any support are not great. Shoes with too much support are not good and shoes with too litle support are not good." - p1

"There is never like one good source of information, you really have to trial and error and ask people that are in similar situations to you." - p1

Apart from the confusion around certain orthopedic advice, the importance of wearing shoes with the correct size was generally agreed upon as being inportant for healthy foot development.

"No matter what the science is, there is no way that a poorly fitted shoe is going to be good for their health." - p1

"So for now until she's six, we can't do anything about [my daugther's toe deformation] except making sure that she has enough room at her toes ... So we're really paying attention now that she's not wearing shoes that are too small." - p4

Social Media as Information Source

Social Media was identified as an important source of foot health and footwear information by multiple parents. It was also a starting point for online consumption of children's footwear.

"I look at social media ... that's how I came up with 'hey wait a minute, but if that's the case ...', and how they explain about your feet, the importance of healthy feet and the impact it has on your whole body. I thought 'wait a minute, for that little one I want to have healthy shoes too'." - p3

"I do get influenced for ideas by Instagram and sometimes Facebook. Because that was someone where the shoes that are round are pushing your toes no matter what … So yeah I would be interested in things like that, because I never thought of it until I saw that." - p1

Determining the Correct Fit

Determining the correct size when choosing new children's footwear can be hard for parents, online and offline. A variety of measuring techniques, previous experiences, store advice and references are used in order to come to a decision. In the end, the choice remains a best guess and can result in uncertainty around the final choice. Finally parents are trying to weigh the need for well-fitting footwear against shoes that will last long enough and will not be outgrown rapidly. The speed growth does vary significantly and makes predicting foot growth hard for parents of young children. Finally, shoe width is generally not taken into consideration, as much as shoe length dimensions.

"We always find it very difficult to estimate how big the shoe should be ... You can never get a good feel. - p4

"My boyfriend and I had a disagreement every time, that I said 'no, it's too roomy' and he thought 'no, it's too small.' So that's why we didn't agree on how big the shoe should be." - p4

"[I measure the width] by feel, because we don't measure our feet width usually." - p1

Tracking Foot Growth

Keeping track of their child's foot growth can be challenging for parents. However, the extent to which this is actually experienced as a challenge varies among parents. Additionally, the ease of determining the correct moment to buy new shoes with a bigger size varies as the child grows and communication skills increase. In general, it can be concluded that parents are playing catch-up with their child's growing feet, rather than buying children's footwear proactively, causing child's foot pains.

"Plus they don't indicate themselves very well yet of 'this is not comfortable' or 'this is too small' you know. That comes now as they get older." - p4

"I forget to check. Yeah, they will tell me their feet hurt. They will tell me it's tight. I don't think to check enough." - p1

"Yeah, it varies a lot, because they have these growth spurts, so I don't know exactly. And we also I think we made them wear shoes that were too small for a while." - p4

Store Assistance and Expertise

Parents note that great customer service is valuable when buying shoes in a physical children's footwear store, as it can radically improve their buying experience and increase the chances of finding a fitting product. However, most parents are experiencing a severe lack of expertise and personal fitting advice from modern footwear retail assistants.

"[In the store] you'll always have a clerk come up to you and ask if you need help and mostly you just ask them for the size you need." - p1

"You just want good advice for a shoe for your children, because the children's feet are still developing and so is their body. And you just want someone in the store who can guide you properly in it." - p3

Cost of Footwear

An average price of children's footwear was considered by multiple parents around forty to sixty euro's. Cheap footwear could be found for close to 15 euro's, while higher cost items were noted to be between 120 and 200 euro's. Products on the high end of the price spectrum were generally associated with more orthopedically correct and high quality options. Especially the footwear of young children with rapid foot growth were considered as a big expense due to the rapid rate of product replacement. The cost of footwear is actively weighed against potential health benefits and easthetic value that the product provides.

"So then we do just look at where there is discount, because she is only going to wear them for a very short time, because, of course, children's feet grow so fast. So you also don't want to spend too much money on it, but at the same time you also want her to have good support." - p4

End-of-Use

Parents have various approaches to the end-of-use of children's footwear, based on the state of the used product and their believes around the impact of used footwear on foot health. The most common options for end-of-use are forwarding the shoes to friends or family, keeping them for a sibling, selling them through online marketplaces, giving them to charity, or disposing them into a recycling collection bin or general trash.

"Everything I have that is no longer useful to us I donate ... I don't sell them. I think that's wrong, because everybody has a different fit." - p3

"If I don't get rid of it, then cousins who like it can have it, and otherwise with Marketplace. I used to do that quite often when she was younger. Now as she gets older the shoes are nice and well-worn and then I take them to the thrift store or into those collection bins." - p2

In addition, friends and family are also the most common way of accessing second hand children's footwear. It is not a product that parents are actively searching for second hand.

"But it's just offered. So it's not like we're looking for used shoes." - p4

Maintenance

A product that supports the child's daily activities, is easy to clean, and requires little protection and cleaning products is considered desirable by parents, and was noted to be a factor that is taken into consideration when choosing new children's footwear. The willingness to invest in product care and dirt prevention are dependent on the initial cost of the product.

"Yes, I think so, my friend says 'yes can get nice and dirty', and I think 'yes a shame, because then they won't last as long'. But you can't always control that, and you also want them to be able to just play nicely so to speak." - p4

"The washing machine works pretty well. But for the other types of shoes not as much, because they are different synthetic fabrics and they look kind of weird after you wash them." - p1

Sustainability

Sustainability is currently not an important factor for parents when they are buying a new pair of shoes for their child. Reasons for this are a lack of sustainable options, awareness around the environmental impact of children's footwear and lack of priority of this factor compared to other factors like product aesthetics. Parents do associate their own behavior around product reuse and donation as a way to be more environmentally conscious.

"But we have simply not had the time or we have prioritized other things [than sustainability]" - p4

"It would be hard for us to find [sustainable options], and if you found it there would be so few options or they would look very terrible, because they are usually not very aesthetic." - p1

"due to the fact that we also reuse shoes from other children, there is of course the importance of sustainability... In any case, we at least do that." - p4

Child's Role in The Selection Process

The role of the child in the selection process of their footwear varies based on the parent, as well as on the child's gender, age and the method of shopping. Girls were generally more involved with style selection, from colors to specific models, from a much younger age than boys. Additionally,

".. she was allowed to choose which color or something she liked. But then we say 'you can choose between such and such', otherwise... So we are very decisive in that. But I think that will also become less and less as time goes on... because she is now really starting to have her own opinion about clothes." - p4

Ease of Use

Multiple parents mentioned the importance of great ease of use for children's footwear, as children of various ages should be able to put on their own shoes. Laces were often avoided.

"I used to have laces for my eight year old when he was maybe five. And he didn't like tying his shoes and then at school when they would come out, he would just double knot it and he couldn't unknot it. It caused a lot of frustration for him, so he has only wanted Velcro for a while and that's fine with me." - p1

Shopping Experience

Parents differ in their attitude towards buying children's footwear, as some enjoy choosing a new pair of shoes for or with their child and see it as nice family activity, while other parents consider it highly inconvenient.

"So we just do that as a family activity. All three of us love shopping, so it keeps us happy." - p2

"Most people like to try shoes on, period. But with kid's shoes it's even worse. It's frustrating." - p1

Parental Influences of Foot Health

Previous personal foot health and footwear experiences, as well as parentral influences were found to be responsible for some of the currently existing foot health and footwear habits.

"And after that my mother kept an eye on shoes she bought for us with 'arch' [in the footbed]. That stayed with me, because I did that for myself for a long time" - p3

"I don't know that a lot of parents think about that, but because my feet are flat now, I try to buy the kids good quality shoes, because I don't want to wreck their feet this early in their life." - p1

Buying Online

Throughout this study, the majority of parents had either partially or fully adopted online shopping for children's footwear. Ease of browsing and access to a large variety of options were the main drivers for this behavior.

"So far we have bought most of our shoes online." - p4

Online shopping, however, also brings about challenges with regards to finding a great pair of shoes, as it is harder to judge the size, less shoes are tried on to find the best fit compared to a physical store visit, and received products might not always meet expectations.

"but online it is difficult to see whether they are really running shoes or not, for children with such small feet." - p3

"And I also find it a hassle to send things back, so that's why we just [order] one thing." - p4

"And if we always buy Vans, then you know you're in the right size" - p4

One participant, living in the US, had previously found success in the use of an online subscription to children's clothes and footwear, in order to save time.

"was doing [subscription service] for a while, because I want to spend the time thinking about different things" - p1

Outgrowing Shoes

The changing rate of their child's foot growth is an important consideration for parents when it comes to choosing a new pair of children's shoes.

"They outgrow them before you can hardly wear any of them. So you have the best litle shoes, even name brand, like Nike and Converse. People give you these things. There is too many for them to wear before they swap out, so that's a shame." - p1

"So if she needs shoes, especially with her size, because she is still growing, she is now having a growth spurt, so she can really be one size for six months and then she is on the next size, we have to take her with us." - p2

Versatility

The versatility for different weather conditions, activities and situations was considered by parents for children's footwear, because of cost saving and practical reasons.

"If [the shoes] can be multi-functional, that's better for me. Because once you have too many shoes, you start losing them and you can't find it. So multi-purpose is best I think for parents usually." - p1

First Child

First-time parents were generally found to be less confident than parents of multiple or older children in their ability to provide their child with footwear with an appropriate physical fit.

"But it is our first child, so we don't have a lot of experience." - p4

Discussion

Most participants included in this study were found to have shifted either fully or partially to buying children's footwear online. These results are not in line with expectations prior to this study. As my personal experience in retail of children's footwear has primarily exposed me to physical retail practices, and since I had witnessed the dynamic and importance of having children involved in the footwear selection process in order to find a correct fit, the data suggesting that most parents currently use online shopping as a means to provide their child with footwear is surprising. For most participants, the wider selection of shoes and the calmer browsing experience outweighed the challenges associated with online shopping, such as difficulties with determining the correct size, return shipments, and accurately assessing product characteristics like aesthetic value and quality. While a wider selection of footwear was important for parents, this also had to be accompanied with tools that made it easy to browse and select options, as the large amount of options could otherwise lead to the customer being overwhelmed and unable to make a choice. Challenges related to finding the correct physical fit were also confirmed to be a result of the differences in fit and sizing systems between brands. Sticking to the same brand or model was, therefore, used as a strategy to make the online purchasing of children's footwear easier. While online shopping provides a wider selection of shoes to choose from, it was also found that generally less shoes are tried on compared to the amount of shoes that are tried during a visit to a physical retail location. Therefore, this could suggest that a shift to online shopping ends up decreasing the chance that children are provided with an optimal physical fit, rather than something that is considered 'good enough'. However, participants were also not confident in the assistance that is provided by modern footwear stores, and considered it their own job to provide their child with well-fitting shoes, online or offline.

The results in this study also suggest that this shift to online shopping strongly affects the role parent and child play in the selection process of new children's footwear. Participants have indicated that their child plays a significantly smaller role when shoes are purchased online than when they are purchased in a physical retail location. While in a physical retail location, both parent and child would browse through the shelves and propose possible options, in a digital environment, the entire selection process was mostly performed by one parent or both parents. In most cases, the child only started playing a significant role once an online order was received. Furthermore, the role of parent and child in the selection process of children's footwear also changed based on the age of the child. Participants indicated that in the early years, their child would not play a significant role in the footwear selection proces. Over time, this dynamic changes. It was noted that the role of parents gradually decreased, while the child would play an increasingly important role in the selection process. Parents would start by making a pre-selection of acceptable options, which would then be proposed to the child. Later on, the child is the one creating a selection of desirable options, before proposing these to their parents and discussing what options are acceptable. This changing dynamic and tensions noted by participants are in line with previous studies around co-consumption of fashion in childhood as discussed in chapter 2.3. An additional finding of this study was a differerence in participation in the footwear selection process between boys and girls. While participants noted that their daugthers would generally start playing a visible role starting around four years of age, boys were generally noted to be less interested in this process until the age of ten.

Participants in this study noted varying degrees of confidence around their ability to provide their child(ren) with correctly fitting footwear. This study indicates that first-time parents can feel particularly challenged in this process, leading to disagreements between both parents and between parent and child. Parents of older and multiple children generally indicate to be more confident in their ability to provide their child with a correct physical fit. Generally, participants noted high levels of awareness of the importance of footwear as part of their childs foot development. The awareness around the health impact of children's footwear extended beyond the feet, into areas like the back, hips and general ability of the child to move. While correct sizing of shoes was unanimously considered to be of great importance for healthy foot development, participants were less certain about other factors that might constitute healthy footwear. Findings in this study align with the literature review in chapter 2.2, indicating a level of confusion as a result of the conflicting views of two schools of thought: barefoot and orthotics. The data from this study does suggest that parents are becoming increasingly familiar with the availability and potential benefits of barefoot shoes for children, as a direct result of barefoot shoe brands and influencers sharing information about this topic on social media.

As discussed in chapter 2.2, previous research has found that two thirds of children are using footwear of insufficient length. This study suggests that a lack of clear and consistent communication between parent and child about the fit of the child's shoes is at the root of this, as shoes are shoes are only replaced once shoes are outgrown to the point were the child is hurting and completely unable or unwilling to put on their shoes. The changing physical fit of shoes is often not top of mind in parents and children, and very young children provide additional challenges with regards to verbal communication.

With regards to the environmental implications of children's footwear consumption, the study suggests that, even though sustainability is often not an important factor in the footwear selection process, parents do engage in behavior that could be considered sustainable. Most notably, various parents regularly engaged in sharing and using pre-used children's footwear, due to this being readily available through family and friends, and to deal with the costs that resulted from the rapid replacement rate of footwear in young children. The use of pre-owned footwear generally decreased as children grew older, as shoes became more worn out during use, and parents were less concerned about cost saving behavior as shoes were outgrown less quickly. However, multiple parents also noted a complete unwillingness to use pre-owned children's footwear, due to their concerns about health implications as a result of wear patterns and shoes taking on the shape of the user's feet. Finally, the ease of maintenance and multifunctionality was noted by participants as an important factor driving footwear selection.

Key Takeaways & Design Considerations

- The design of a new system for children's footwear should consider creating a sufficient variety of style options, while being aware of the risk of choice paralysis. Careful curation of a good selection and easy selection and filter tools are needed to ensure a convenient and desirabale shopping experience.
- For the introduction of a new system, special attention should be paid to social media and the role it plays in educating modern parents about the foot health and footwear of children.
- A new shopping experience should focus on re-engaging the child into the footwear selection process to ensure a good identity, social and physical fit. This experience should be fun for the child, while being convenient and informative for the parent.
- The design of the system should inspire and facilitate more pro-active consumption habits around children's footwear, by helping children and their parents to track the child's foot growth and fit in between store visits.
- The design should aim to prevent complicated sizing systems and make it easy for parent and child to understand the child's physical fit needs.
- High quality assistance in children's footwear retail is considered highly desirable, but rare to find. High quality assistance is important to help parent and child learn more about physical fit, make it easier to find appropriate styles and provide an enjoyable store experience.
- First-time parents were found to be less confident about their ability to provide their child with an appropriate physical fit. They are also more likely to be open to new solutions to help them with children's footwear.
- Children's footwear should be designed to be multipurpose, easy to maintain, and easy to use by the child.
- Parental sharing networks for children's footwear can be found in many places, effectively extending the lifetime of lightly worn footwear. Reuse is less popular for older children as they tend to wear out their shoes more.
- Some parents are actively against the use of pre-owned children's footwear, as they believe that it could negatively influence their childs foot and gait.
- The design of a new system should consider the changing dynamic between parent and child in the selection process as the child grows older.
- The willingness to pay per pair of children's shoes significantly increases as the child grows older and the rate of shoe replacement goes down.
- The study suggests that based on the family and the store, physical retail can either be a pure inconvenience, or a highly enjoyable family activity.

3.2 Mapping The Customer Journey

In this section, a visual overview of the current customer journey of children's footwear is created. This overview combines insights from the previously described exploratory end-user research, with the theoretical foundation and my personal experience in retail of children's footwear.

While the end-user research provides direct in-depth insights into the customer experience of parents as end-users of the system that is designed is this thesis, this study does not include the perspective and experiences of children directly. This is partly due to restrictions and limitations around the involvement of children in the context of this project. However, prior to the start of this project, I have personally been exposed to the context of physical retail of children footwear through my work as a retail associate in a children's footwear store (see figure 6) for over a year. Therefore, the insights from exploratory end-user research and the literature review in chapter 2 were combined with insights from direct field experience in a physical children's footwear retail context. In this way, this project aims to include the child's perspective and interactions, and provide a more complete basis for the design of a new product-service system for children's footwear. The information was translated into a customer journey map (see figure 7), divided into six phases, every phase describing a distinct set of actions as part of the consumption of children's footwear. These phases include: Problem Recognition, Information Gathering, Evaluation of Options, Final Decision, Use & Maintenance and End-of-Use. For each phase, the 'job to be done' and tools of parent and child are described. Additionally, the factors leading to a positive and those leading to a negative experience are presented. In combination with the key takeaways and guidelines for design presented in the previous section, this creates a basis for creating a system that is user centered.

Figure 6: Interior Nolten Kids (Marcel Berrens Design, n.d.)

Problem Recognition

Job to be Done

Parent: Determine if it is the right time to buy new shoes for their child.

Child: Becoming aware of current shoes becoming insufficient and communicating this to the parent

Tools

Parent: Foot measurement tools, using their hands and eyes, asking their child questions, checking the seasons

Child: Signalling through behavior change, direct communication to parent

− Parent's concern about sustainability impact	+ Opportunity to select a new pair of shoes
− Child experiences foot pain from outgrown shoes	− Confusion around the timing to buy a new size
	− Parent confronted with need to spend money

Information Gathering

Job to be Done

Parent: Figure out the available styles and footwear needs of their child

Child: Play and interact with other children in the store, have influence on the style orientation process

Tools

Parent: Prior experiences, information from familiar and professional voices (offline and online), communication with child

Child: Direct communication with parent

− Lack of clear information around foot health	+ Access to easy to browse large amount of options
− Hard to determine the correct size online	+ Personal and accurate store advice
− Visiting a physical store is time and energy intensive	− Having access to too little sufficient style options
− Too much or too little store assistance	− Being overwhelmed by too many options

Evaluation of Options

Job to be Done

Parent: Comparing and narrowing down the options

Child: Influencing the selection of options

Tools

Parent: Online reviews, store advice, communication with child

Child: Communication with parent or store assistant

− Hard to judge product durability	+ Parent seeing their child develop their own style
− Disagreement between parent and child	+ Child feeling they have a level of control
− Received online order is different than expected	− Hard to compare fit between options

Final Decision

Job to be Done

Parent: Make a final decision on which shoes to choose and complete purchase

Child: Making sure that the final decision aligns with their desires

Tools

Parent: Webshops, physical store, different payment options

Child: Direct communication with parent

+ Parent seeing their child happy with new shoes	+ Validation of a good choice by store assistant
+ Useful product maintenance advice	− Product of choice is not available
+ Relief of having made a choice	− Complications during checkout process

Maintenance & Use

Job to be Done

Parent: Keep shoes in use for as long as possible, keeping an eye on physical condition and fit of the shoe

Child: Use the shoes as much as possible, being aware of the shoe getting too small

Tools

Parent: Weather forecast, shoe brush, water, soap, water repellant, anti-odor spray, shoe repair shop, shoe-laces

Child: Weather forecast

+ Child can easily use the shoes without help	− Shoes are outgrown rapidly
+ Shoes are comfortable and child wears them	− Shoes breaking down before being outgrown
+ Shoes are durable and easy to maintain	− Shoes getting dirty or smelly
+ Shoes are appropriate and versatile in use	− Remembering to check if the size is still correct

End-of-Use

Job to be Done

Parent: Dispose old shoes and make space for new shoes, assess product quality, retain value of old shoes

Tools

Parent: Friends and family, collection bins, charity, second hand marketplaces (offline and online), social media, direct communication tools

+ Being able to forward shoes to friends/family	+ Getting money for used shoes by selling them
+ Having easy access to collection bins	− Feelings of guilt and environmental concern
+ Giving used products to charity	− Used shoes becoming worthless

Figure 7: A visual customer journey map

04

3D Printing & Footwear

This chapter introduces the topic of 3D printing in footwear. It provides a summary of 3D printing methods that are currently applied for the creation of wearable footwear, and an overview of the environmental and social implications of shifting from traditional footwear manufacturing methods towards 3D printing. Furthermore, it is discussed how 3D printing, computational design and data enable a shift from mass production towards mass customization. This chapter concludes with an overview of challenges related to an industry shift towards 3D printing for the creation of consumer products at scale.

4.1 An Introduction to 3D Printed Footwear

Stereolithography (SLA)
Fused Deposition Modelling (FDM)
Powder Bed Fusion

4.2 Environmental & Social Impact

Local Mnaufacturing
Distributed Production Networks
Resource Efficiency
Material Revolution
End-of-Life
Challenges

4.3 Mass Customization

Computational Design
Data Collection

4.4 Challenges Going Forward

Production Time & Product Quality
Education
Rethinking Positioning
Personalization
Data Security
Intellectual Property

Key Takeaways & Design Considerations

4.1 An Introduction To 3D Printed Footwear

This section provides an introduction to 3D printing as a method of footwear production. The three most commonly used method of 3D printing in footwear are summarized, and current applications and brands in the space are discussed.

Introduction

Three-dimensional (3D) printing is a method of producing three-dimensional objects by joining materials layer-by-layer under the direction of a computer (Nadagouda et al., 2020). The use of 3D printing has been steadily growing in the footwear industry. Initially, 3D printing was mainly used to explore ideas earlier in the design and development process of new footwear, as it represented an agile and cheap way to turn 2D sketches and 3D computer models into physical objects that could be used for product testing and iterating, early market-fit validation and to speed up the overall product development process (Ukobitz & Faullant, 2021). At this point in time, functional prototypes using 3D printing were difficult to make as the materials used for printing were not flexible or strong enough (Luximon & Luximon, 2021). However, a quick Google search or even a visit to some footwear stores will immediately show that 3D printing technology in the footwear industry has become far more than just the prototyping tool it once was. 3D printing, as well as other additive manufacturing technologies, have undergone significant developments, and big and small brands have steadily been adopting and integrating these technologies into their production processes. The implementation of 3D printing technology into commercially available products ranges from separate parts to full shoes, printed as one part.

Stereolithography (SLA)

Stereolithography is another form of 3D printing that has seen growing adoption for the production of footwear. With SLA, a laser is used to build an object layer-by-layer successively by solidification of a liquid photopolymer. There is a wide range of material formulations available, from soft and hard, to materials filled with secondary materials and different mechanical properties (Luximon & Luximon, 2021). This production technique was used by Adidas in collaboration with Carbon® to create a 3D printed midsole that is now available to consumers in a range of Adidas running shoes (see figure 8). This production technique allowed for the creation of a midsole with precisely controlled varying structural densities throughout, to create multiple functional zones to optimally absorb the respective loads that occur during running (Trapp et al., 2022). SLA is currently also being used by some small brands and individual footwear designers, like Ica & Kostike, SCRY Labs and Aliveform, to bring fully 3D printed footwear to market. Resulting products are generally recognizable by a soft and high quality finish.

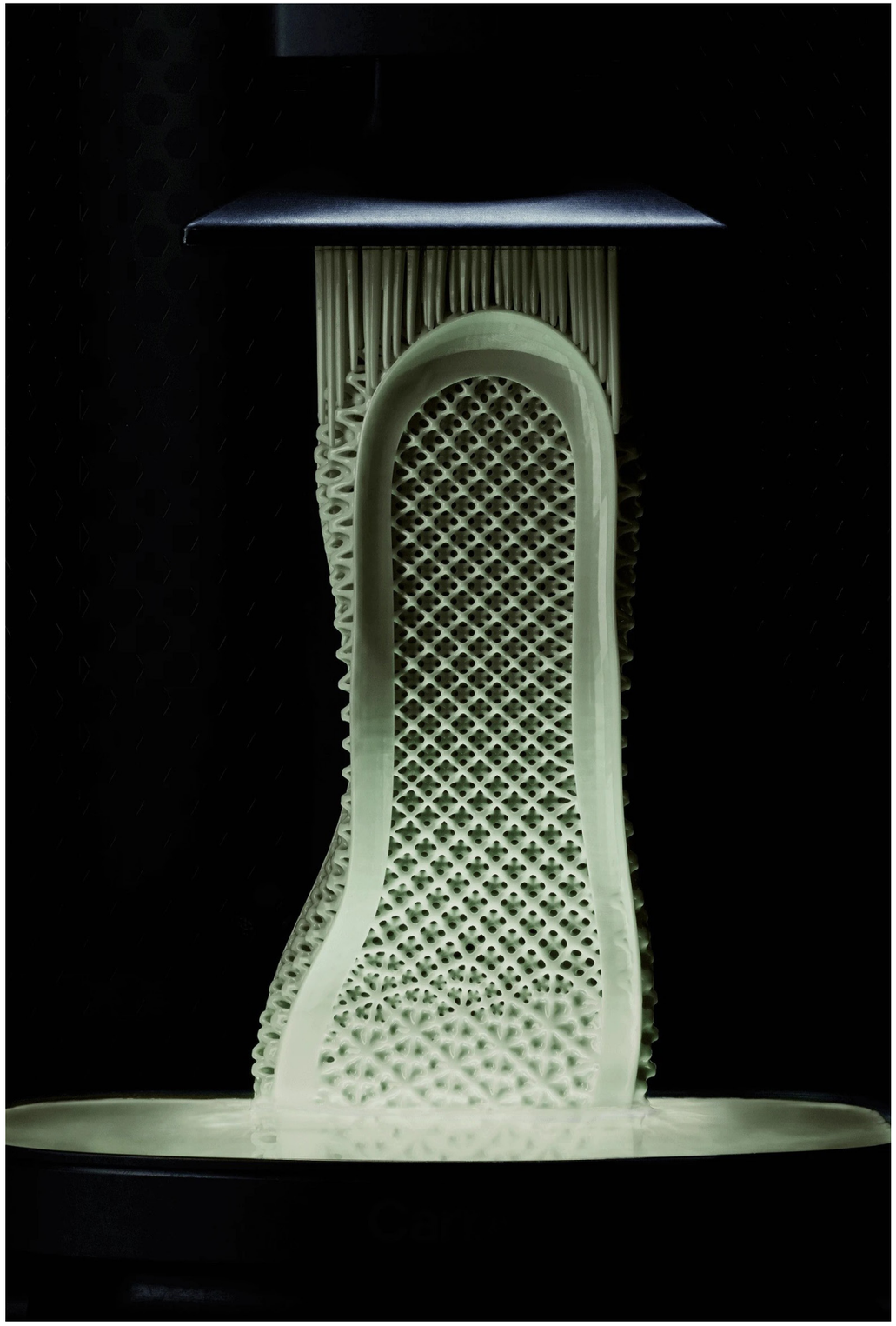


Figure 8: SLA printing process of midsole unit by Carbon and Adidas (Carbon, n.d.)

Fused Deposition Modelling (FDM)

A couple of different 3D printing techniques have become increasingly popular for the production of footwear. One of these techniques is Fused Deposition Modeling (FDM). With FDM, heated thermoplastic is extruded through a computer-controlled nozzle to build an object layer-by-layer on a platform (Luximon & Luximon, 2021). With this technique, a wide selection of materials can be used in the form of filament that is fed into the nozzle as a solid. FDM printers had already become popular professionals and hobbyists in the 3D printing community due to its affordability and general ease of use. However, in recent years, individual footwear designers, manufacturers and brands have started to use this way of 3D printing to create footwear that can be used directly by the end-user. Fused Footwear was founded by Philippe Holthuizen in 2017, with the idea that, if you have the skill, you can now build a brand or business with 3D printing, without the need for outside investments or help. This one man operation is still creating footwear from a facility in Hong Kong, catering to early adopters in the footwear space (Kan, 2021). Zellerfeld is another brand that is pushing FDM 3D printing as a viable alternative for traditional footwear manufacturing. The brand is quickly scaling up and developing printers specifically for the production of fully 3D printed footwear (see figure 9), as well as new materials to improve the overall product characteristics and performance that can be delivered through 3D printed footwear. In contrast to Fused Footwear, Zellerfeld has established itself as footwear manufacturer, rather than a footwear brand. Footwear is being created in collaboration with fashion brands, as well as individual footwear designers, who can turn their 3D models into commercially available products, which are then sold directly through Zellerfeld's online platform. In the past years, Zellerfeld was able to build their first factory, rapidly increase the amount of printers and go from closed to open beta, allowing everyone to order their pair of 3D printed shoes and bringing them closer to fulfilling their mission of putting 3D printed shoes "on every foot in the world" (What the Tech?, 2021).

Figure 9: 3D printed shoes by Zellerfeld and Heron Preston using FDM © 2023 Zellerfeld

Figure 10: 3D printing process of HP for Botter using Multi Jet Fusion (Ricciardi, 2023)

Powder Bed Fusion

Selective Laser Sintering (SLS) and Multi Jet Fusion (MJF) are both based on Powder Bed Fusion and use layers of powder that are bonded by means of a laser or by using heat and a liquid binding agent. These printers are generally much larger in size, compared to the average FDM and SLA printers, and they require significantly more higher investment costs. However, brands using this method of 3D printing can benefit from the larger build volume, comparatively high print resolution and accuracy, and there is no need for additional support structures, enabling small batch production (Luximon & Luximon, 2021; MJF vs SLS, n.d.). Both SLS and MJF are currently being used for the production of footwear parts, as well as full footwear consisting of one part. Caribbean Couture brand Botter partnered with Reebok in 2023 to create a range of sneakers silhouette, as well as slides, that were fully printed with MJF by HP (see figure 10) (Cruz, 2023). HP also partnered with running brand Brooks to create 3D printed midsoles for new running footwear that are claimed to deliver high amounts of energy return (Running on HP, n.d.). Finally, during the presentation of Dior's FW23, Kim Jones presented a two pairs of fully printed shoes using powder bed fusion technology, showcasing the luxury brand's interested in exploring these new technologies to create new footwear (Here's How Dior Made Its 3D-Printed Shoes, 2023).

4.2 Environmental & Social Impact

In this section, the environmental and social implications of an industry shift towards 3D printing for the production of footwear is discussed. Both opportunities and challenges related to printing are discussed to provide a basis for the development of a circular product-service system.

Introduction

The implementation and scaling of 3D printing technology for the production of footwear has significant implications for the entire supply chain of footwear brands. With the introduction of shoes that are (largely) consisting of one part, made out of one material, it is likely that we will see a huge shift in the way footwear is designed and produced. Previous research has shown that traditionally a single shoe can contain 65 discrete parts, made of many different materials, that require 360 processing steps for assembly (Cheah et al., 2013). With the use of a 3D printer, this is reduced to one part, using one material, in one location and with no separate assembly steps. This might impact the footwear industry in different ways with regards to social and environmental sustainability.

Local Manufacturing

First of all, 3D printing allows for a shift from global production, and extensive and untransparent supply chains, to local manufacturing of footwear. As most additive manufacturing processes do not require large factories or challenging logistical connections, it can become easier for new startups and even individual designers to set setup smaller and decentralized production structures, which can lead to a reduction of transports within the supply chain with possible emission savings (Trapp et al., 2022). Additionally, most footwear brands are currently dependent on a network of different suppliers for the different components and assembly steps for the creation of their products. This does not only lead to extra complexity, but it can also make it harder for brands to fully understand and be in control of how their products are made. Responsibility is, therefore, often relayed to others in the supply chain, as brands and manufacturers rather avoid the responsibility to assess their full supply chain, which in many cases might be a daunting and intensive process. However, change is needed, as research has shown that sweatshop based labor exploitation is not only associated with 'third world' regions, but also endemic across the eastern and central European footwear sector (Selwyn et al., 2020). Efforts are being made by at least some brands, like sustainable footwear brand Allbirds who has led the way in terms of maintaining a small, tight-knit supply chain, and making sure that their partners are adhering to their standards of sustainable and ethical production (Allbirds, 2022). The introduction of local manufacturing, however, might make this much easier for big and small businesses as production can be local and in one place.

Distributed Production Networks

The introduction of 3D printing brings about possibilities to create a more distributive system that blurs the lines between producers and consumers. So called 'prosumers' could form the basis of a new type of peer-to-peer economy, where everyone can be both maker and user, as long as you have access to a 3D printer and you can download or create the necessary printing files (Raworth, 2017). 3D printing networks and platforms are being built to link owners of 3D printers with customers, in order to increase the utilization of printing capacity (Despeisse & Ford, 2015). Raworth (2017) stated that 3D printing, in combination with digital networks and sustainable energy, will result in a type of community ownership that is created collectively. The first signs of the creation of such a distributive system are now starting become visible in the footwear industry. Zellerfeld has created a Discord group that allows anyone who is interested to join the conversation and openly share information with each other around 3D printing footwear. The community forms an important source for individuals and businesses to start printing their own footwear at home and it stimulates the creation of open-source

Figure 11: Inside the Zellerfeld 3D print farm for footwear © 2023 Zellerfeld

information. The creation of such a system and sharing of information also happens through social media platforms like Instagram, where designers, developers, producers and consumers are able to find each other directly, share information, and develop products. In addition to producing their own 3D printed footwear, Ica & Kostika openly sells 3D printing files of their footwear models and encourages people to print their own footwear with these files at home. Such distributive systems are vastly different from the traditional footwear system, where scale of production, minimum order quantities, retailers and large investment costs create significant barriers for new market entrants. Traditionally, the development of a new shoe could cost anywhere from fifteen to more than a hundred thousand euros, and require upfront investments for the creation of lasts, cutting patterns and molds for different sizes. With a shift towards additive manufacturing, it will be easier for new startups and individual designers to start production, as there is no need for such upfront investment or inventory creation, making them more agile and able to adapt to market needs and information that helps rapid product iteration to better meet customer needs (Ukobitz & Faullant, 2021). As 3D printed footwear factories can be easily integrated into environments that are not suitable for conventional production processes, production in new places, such as inner city retail shops, rural and economically not so strong regions, can help to create direct economic added value (Trapp et al., 2022).

Democratizing the footwear industry has been the core mission of Zellerfeld since its inception (Forbes, n.d.). Other than providing every designer with access to footwear manufacturing and radically lowering barriers for entry through the creation of its printers and manufacturing facility (see figure 11), the concept of democratization can also be found in the way the end customer truly decides what gets made by buying a certain style. Like representatives, footwear brands and designers are now tasked with figuring out the customer's footwear needs and translating these into offers for the customer, allowing people to vote with their money. It will be interesting to see if such an approach will create a meaningful shift in fashion cycles too, as traditionally, footwear trends have largely been dictated by choices made in the boardroom of large fashion and footwear corporations, which have been more or less force fed to the customer until it became accepted and eventually the norm. The rise of

on-demand footwear manufacturing platforms and 3D printing factories is expected to increase, as footwear brands like Vivobarefoot, world's leading barefoot shoe company, are announcing a shift to on-demand manufacturing with local 3D printing production hubs, starting in the UK and soon expanding to Germany and the US (businessfocus, 2023). In addition to fully 3D printed footwear, companies like 3DTI are developing local manufacturing solutions that combine 3D printing technology with methods like thermoform injection molding, generating a faster, more affordable and scalable way to create certain tailored products (3DTI, n.d.).

Resource Efficiency

The adoption of 3D printing in footwear production could mean a significant improvement in resource efficiency when compared to traditional manufacturing. The footwear business model relies on buyers predicting the amount of product that they will sell ahead of time. This results in leftover stock at the end of every fashion season. The current system incentivizes brands to overproduce, as from a business perspective, selling out is more expensive than having extra product that never gets sold. This results in fifteen to forty five billion of the estimated 150 billion garments that are produced every year, never being sold and being send straight to landfill or incineration (Chan, 2023). In addition to the Extended Producer Responsibility legislation that is currently being implemented to hold brands accountable for the waste their products cause at end-of-use, the EU has announced new legislation, in December of 2023, to crack down on 'fast fashion' and reduce waste (Rijksoverheid, 2023). In this provisional agreement for a revised framework for eco-design, a ban on the destruction of unsold goods was announced, including footwear as a priority product (Popp, 2023).

Due to closeness to the consumer and personalization capabilities, 3D printing and other additive manufacturing technologies could facilitate an industry shift towards manufacturing on-demand, minimizing inventory waste, reducing inventory risk with no unsold finished goods, while improving revenue flow for brands as goods are paid for prior to being manufactured (Chen et al., 2015; Despeisse & Ford, 2015). Startups and mall footwear brands could especially benefit from such a made-to-order model, as a variety of fashion brands have already demonstrated its market desirability and viability (Chan, 2023). In addition to minimizing the amount of unsold products, additive manufacturing could reduce the amount of raw materials needed for every item that is produced. As the product is created layer-by-layer through a process that is additive rather than subtractive, manufacturers will be able to create products with optimized geometry or structures, often unachievable through other manufacturing methods (Despeisse & Ford, 2015; Öberg & Shams, 2019). Additionally, waste that is created during the manufacturing process can be minimized, as most of the material that is used is directly added to the product that is manufactured. 3D printing also generally does not require the fabrication of molds or other auxiliary materials that are usually needed in traditional manufacturing (Chen et al., 2015).

Material Revolution

Footwear has traditionally involved the use of animal derived materials. The process involved with transforming animal hides into usable leather for footwear manufacturing is a complex and generally very toxic and wasteful one (Food and agricultural organization of United Nations, 2006) (Motawi, 2017). The tanning is a very important step in the leather production process, but a very polluting one as well. The dumping of solid and liquid waste that contains leftover chromium and other hazardous compounds, in under regulated areas, poses threats to the environment as it enters regional water systems, inciting respiratory problems, infections, infertility, birth defects and cancers in animals throughout the supply chain. The other drawback of chrome tanning and the preceding leather treatments is linked to the health threats they pose towards local leather workers. A lot of the leather tanning industry is located in developing countries like India and Bangladesh, where regulations are insufficient and there are no funds to provide a safe and healthy working environment. In these places, workers continually come into contact with chemicals as they are standing inside the treatment bathes and do not get the necessary protection. Injury from heavy machinery and drowning are also real problems that leather workers are dealing with, and a growing number of studies is finding connections between dyes, solvents, leather dust and tanning, and several types of cancers (Tarantola, 2014). Global Fashion Agenda (2016) stated that, together with silk and cotton, cow leather is the fashion material with the greatest 'cradle to gate' environmental impact, when assessed on chemistry, abiotic resource depletion, eutrophication, global warming and water use. Complex supply chains, a general lack of transparency and traceability, and misleading leather labeling practices make the shift to sustainable and ethical leather a great challenge (Cernansky, 2020; Jackson, 2023). However, since the leather industry generally presents leather as a byproduct of the meat industry, it is difficult to quantify the exact contribution of the leather industry to the overall environmental impact. Still, the leather industry should never be separated form cattle raising, as leather remains a very lucrative product resulting from livestock farming. In fact, leather was found to account for approximately 10% of the animal's total market value, making leather the animal's most valuable part, pound for pound (Lennon, 2013). Therefore, moving away from the use of leather, as well as certain other natural materials in footwear, could mean a significant improvement with regards to environmental and social impact, and it would fall in line with a cultural shift towards increasingly vegan lifestyles and more concern about animal welfare. In addition to the petroleum based substitutes that have been popular in traditional manufacturing, as well as 3D printing, new material science and manufacturing companies are introducing biobased that are fully compostable at end-of-life. Neffa is a startup the promises to push the use of mycelium as a textile replacement. Whereas current mycelium based leather alternatives are produced in sheets to be cut and sewn, Neffa's vision is to make use of the growing nature of the material. Through informal conversations I learned that the goal is to create 3D printed molds and grow mycelium inside these molds to form products directly into their final shape, without cutting waste or fasteners. BioCir® is another cutting edge material, developed by material science company Balena, that can be 3D printed and is supposed to combine the durability and flexibility of traditional plastics with the ability to biodegrade safely in industrial compost facilities. A first proof of concept was delivered in 2023 (see figure 12), and further adoption of the material was announced by Vivobarefoot (businessfocus, 2023).

Figure 12: 3D printed and fully compostable slides by Kitty Shukman and Balena (AZO Materials, 2023)

End-of-Life

Traditionally, end-of-life has not often been considered by footwear brands and designers. Modern footwear is often assembled with a combination of glue, cementing and stitching, making it practically impossible to be disassembled efficiently and effectively at end-of-life. The result is that most footwear eventually ends up in incineration or landfill elsewhere on the planet. Uganda has recently completely halted the influx of clothing that is discarded by Western countries, in an effort to reduce the competition that local clothing brands face in their own markets (Lindhout, 2023). Other solutions to extend the life of footwear are also lacking, as the use of sneakers has drastically reduced footwear maintenance and repair activities. Organizations like WEAR and Fast Feet Grinded are now starting to develop systems to extend the life of footwear and efficiently retrieve some of the value that stuck in used and discarded footwear. 3D printed footwear, however, might offer new opportunities for the creation of products and systems that enable more efficient and effective value retention, by optimizing ease of maintenance and end-of-life recycling. As 3D printed footwear generally consists of a single thermoplastic material, resulting products are often naturally water and dirt repellant, machine washable and easy to recycle. This facilitates the reuse of materials for the creation of new products, without any need for disassembly.

Challenges

3D printing also has a variety of challenges that have to be overcome with regard to its potential societal and environmental impact. First of all, the different printing techniques produce parts with varying degrees of recyclability for produced parts, as well as unused material that results from the manufacturing process, and material that is needed for the creation of support structures in 3D printed footwear. FDM as a printing method generally produces fully recyclable parts and support structures in cases where products are created with a single material, as its filament is made from thermoplastic materials that can be remelted and reshaped, and material contamination can be avoided. Materials will, however, still degrade with every cycle and new virgin material is generally added to new products to maintain desirable product qualities such as durability and flexibility. In powder bed printing methods, such as SLS and Multi Jet Fusion, nylon or TPU powder is commonly used to create 3D printed parts without the need for support structures. However, due to the heating process that is needed to fuse the powder layer-by-layer, consistent degradation of unfused powder occurs that limits the reusability of unfused powder. Powder bed printing methods also suffer from similar material degradation resulting from recycling as is the case with FDM printing. Furthermore, practical recycling of products resulting from either FDM or powder bed printing methods are currently lacking due to a lack of established recycling networks for the materials that are commonly used in these production processes. Additionally, 3D printed footwear manufacturer Zellerfeld has previously announced that dyeing of products by users will result in products that cannot be recycled into new footwear. With regard to recyclability, SLA is very different from FDM and powder bed printing methods. SLA makes use of thermoset resins that, once cured, cannot be remelted or reshaped in the way that thermoplastics can. Research is investigating the possibilities for chemical recycling methods, but these processes are not yet widely available or as economical as those for thermoplastics. Additionally, the process generates waste in the form of supports, failed prints, and uncured, excess resins, which are considered hazardous materials. Finally, the recycling process can be further complicated by the use of post-processing steps that are meant improve product qualities.

Figure 13: Salomon INDEX.01 (Salomon, 2023)

Another challenge of current 3D printing methods in footwear, is the use materials that are derived from non-renewable fossil fuels. Multiple organizations are continuously investigating and developing new bio-based and biodegradable materials that are suitable for 3D printing, but application to end-production and mitigation of reliance on finite resources is currently very limited. Business model innovation and collaboration will also be necessary to promote more efficient use of finite resources. Businesses are currently still limiting the use of recycled materials to the creation of the same products, which eventually always leads to low recycled material percentages and continuous need for more virgin material. Two different post-consumer recycling strategies for TPU have also been demonstrated by Adidas and Salomon. With Futurecraft Loop, Adidas created a running shoe, fully made of TPU, which was supposed to be fully recyclable into the next pair of running shoes. However, the project also demonstrated current limitations to recycling and material quality. Even though the single material running shoes could be fully recycled into new shoes, only about 10% of the material in the resulting shoe was recycled, and mostly in the hard outsole, tongue label, eye stays, and some internal reinforcements (Bain, 2019). Salomon demonstrated a different approach with their Index 01 running shoe (see figure 13). The TPU from this shoe was not recycled into a new pair of running shoes, but it was used to create other products, like a ski boot shell, making use of the different required material properties and allowing for more efficient and effective use of recycled materials (Introducing the Index.01 Recyclable Running Shoe, n.d.). Cross industry partnerships between different brands could take such concepts to the next level and enable more efficient, connected and open-loop material networks (Raworth, 2017).

Another challenge for 3D printing as a manufacturing method is the amount of energy that is required for production. Previous research found that the emission of shoe printing is significantly influenced by the emissions associated with the electricity consumed by the 3D printer. The carbon emissions of 3D printed footwear from Zellerfeld were found to be similar to that of more traditional athletic footwear. However, it was also stated that, although 3D printed shoes currently still result in relatively high carbon emissions, overall environmental impact might be different. While emissions of customer-independent mass production can cause lower emissions due to efficiency, it also leads to overproduction and mass destruction of unworn shoes, which changes the ratios. Additionally, it was noted that 3D printing as a footwear manufacturing process is still novel, and that there is potential for process optimization, resulting in significant energy savings and carbon emission reductions. Reducing printing times, improving energy efficiency, reducing print failure and increasing renewable energy use is considered essential (Trapp et al., 2022).

The use of plastics in 3D printing also raises concerns with regards to the creation of micro plastics, as micro plastics that result from the use of footwear can significantly affect the natural environment. A variety of studies has previously stated that micro plastics in the form of shoe sole fragments spread through the environment, contaminating the soil and negatively impacting biodiversity (Araújo et al., 2022; Forster et al., 2023b, 2023c, 2023a; Kim et al., 2022; Lee et al., 2022).

4.3 Mass Customization

This section discusses the possible shift from mass production to mass customization of footwear, as a result of a shift towards 3D printed footwear, and supported by the introduction of computational design and activities around foot data collection.

Introduction

While footwear used to be a personalized product of manual labor from the hands of a skilled artisan, the industrial revolution changed footwear into mass produced items. Options were reduced and items became identical, resulting in reduced costs and greater accessibility. However, this also meant that shoes would no longer fit someone perfectly, and the focus of footwear consumption changed from getting one perfectly fitting pair to multiple pairs with an acceptable or sufficient fit. Additive manufacturing techniques, such as 3D printing, have the potential to revolutionize the production of footwear, and move the industry from mass production to mass customization, offering personalization at scale (Salles, 2011; Ukobitz & Faullant, 2021).

Figure 14: Volumental foot scanning platform (Volumental, 2021)

Computational Design

The shift to mass customization and additive manufacturing are enabled by the adoption of computer aided design (CAD) in the footwear industry. When CAD was introduced in the footwear industry over fifty years ago, it was mainly used for 2D pattern generation from shoe designs. 3D CAD became popular for the design and manufacturing of shoe-lasts and soles. Currently, 3D CAD is increasingly being adopted for the design and development of all footwear parts. The next evolution or extension of CAD came in the form of computational design. Where CAD traditionally empowered designers and developers to have direct control over a created object and its geometric shapes, computational design uses algorithms to generate geometry. In this case, designers and developers define

Figure 15: Personalized 3D printed orthotics (Dynagraph, 2023)

the goals and constraints in the form of design parameters, and the system rapidly generates designs that fit these parameters. In combination with biomechanical data and foot scans, computational design software currently allows for the creation of personalized orthotics (see figure 15), and custom fitted shoes that match the contours and pressure patterns of an individual's feet. Such systems resemble the way in which personalized footwear was made in the past, but it makes it scalable, faster and more advanced, due to data collection, automation and rapid iteration.

Data Collection

Obtaining the necessary foot data to feed into the computational design process involves scanning people's feet. A variety of organizations offers high resolution foot scanning solutions, in the form of physical platforms that a user can stand on, or mobile applications that allow the user to create a 3D model of their feet through the camera on their phone. Companies like Volumental (see figure 14) and Safesize use such static foot data to help people with finding correctly fitting footwear, by either comparing the foot scan data to that of scanned shoes, or by comparing foot scan data of an individual to that of other people and their satisfaction with certain shoe models, to find out which shoes most likely fit different types of feet. Additionally, Safesize works on algorithms for recommending healthy fitting shoes for children, and predicting foot growth. However, a limitation of commonly commercially available scanning technology in stores, as well as some computational models used for the creation of personalized footwear, is that they only take into account the static foot information. As feet are changing dynamically in movement, creating truly personalized footwear that supports an individual's movement optimally, would require additional information. A visit to a podiatrist can usually deliver a more complete image of a person's feet and entire body in motion, as clients are asked to walk around, and a trained health professional observes and assesses the movement of an individual carefully.

4.4 Challenges Going Forward

Apart from the previously stated environmental challenges related to 3D printed footwear, there is a series of other challenges that need to be overcome for mass adoption of 3D printed footwear and a successful shift towards mass customization.

Production Time and Product Quality

One clear challenge is the amount of time that it takes to create single 3D printed shoe, as this currently takes hours or days, compared to traditional footwear manufacturing techniques, such as molding, which generally takes minutes or seconds. This results in higher costs per product and long waiting times for customers. As Zellerfeld is scaling up production and adding hundreds of printers to their production site, the expected delivery time for a pair of 3D printed shoes is still close to six months, due to excessive demand and a long waiting list as a result of limited production capacity. Another challenge for production efficiency arises from the risk of misprints. As printed footwear is created layer-by-layer, manufacturers have to precisely control the printer, print settings and printing environment to ensure that misprints are prevented. Research is currently investigating several options to decrease printing defects and optimize printing speed through the application of deep learning models that are able to detect faults in real time and change print settings in order to accelerate and slow down printing speed, and optimize production time and quality (Kreutz et al., 2022).

Education

Furthermore, previous research has identified the current lack of available qualified and skilled personnel that is needed for the adoption of 3D printing, 3D scanning and a shift towards mass customization in footwear (Ukobitz & Faullant, 2021; Luximon & Luximon, 2021). Overcoming the skill gap will require footwear designers and developers, who have traditionally worked through sketching and 2D CAD, to become capable of using 3D and computational design software. New teaching and training of footwear technologists for footwear designers and footwear industries are required (Luximon & Luximon, 2021). Additionally, factory workers will have to be trained to operate new machinery. It is also expected, however, that workers can be qualified quickly, due to a minimal amount of work steps and, often, little handling of hazardous substances (Trapp et al., 2022). Furthermore, the training of designers, developers and factory workers in the fields of additive manufacturing could lead to highly transferrable skills that are easily applicable to different fields and sectors, possibly making it a valuable long-term investment.

Rethinking Positioning

An interesting challenge for footwear brands and the different organizations along the traditionally extensive footwear supply chain, is based around the need to rethink positions and roles in a future of additively manufactured products (Öberg & Shams, 2019). As traditional footwear can be made of up to 65 different parts, a large network of suppliers and manufacturers is responsible for the production and assembly of a shoe. With a transition to 3D printed, personalized footwear that is made from a single part, this supply chain is entirely disrupted. Therefore, brands and suppliers have to rethink which parts of development and production they will do in-house and which they will outsource. Zellerfeld already demonstrates an entirely new approach to footwear design and manufacturing. All footwear is designed by individual designers and existing fashion brands, but it is produced by Zellerfeld and sold on their platform, on-demand, and customized to the customer's foot data and/or fit preferences.

Personalization

With regard to personalization, there are additional challenges to be solved. Some footwear brands have decided to release footwear with 3D printed parts, without any possibility for individual customization or on-demand production models, completely ignoring some of the important opportunities that additive manufacturing can provide. For companies that do decide to offer a level of customization, there are different ways to approach this. Four levels of customization have previously been defined, highlighting a difference between size and fit customization or custom made approach on the one hand, and a best fit approach on the other. In one case, a shoe is made to exactly fit the dimensions of a user's feet, while the other method is based on identifying the shoe-last style combination that is the best approximation of the customer's feet dimensions and requirements (Boer et al., 2004; Salles, 2011). Aside from the level of objectively achieved personal fit, perception and customer satisfaction has to be considered, as they might not necessarily correspond to a higher level of fit customization. As customer satisfaction can result from the difference between expectations and result, the high expectations arising from promises around fully customized fit might have a detrimental effect on customer satisfaction ultimately. Therefore, the level of fit customization and communication around this has to be carefully considered.

Data Security

Additionally, privacy is of great importance with the introduction of obtaining personal foot and gait information at scale. In recent years, it was published that Chinese authorities have begun deploying new surveillance tools using gait recognition software, developed by Watrix, which is claimed to be able to identify people from up to fifty meters away, with their back turned or face covered, using people's body shapes and way of walking (Kang, 2018). With foot and gait information joining the every increasing amount of personal and biometric data that is collected, it is important that organizations are cautious about the collection, processing and storage of such data.

Patents & Intellectual Property

Finally, the development of innovative production technologies and new materials has been essential for many footwear brands to stay competitive. This is followed by companies patenting such technologies and materials in order to prevent competitors from using them. Some new entrants in the footwear industry have focused on driving a more open source and collaborative approach to footwear innovation, in order to accelerate the shift towards circular and more sustainable manufacturing. However, patents do remain a challenge for new entrants, also in the currently developing 3D printed footwear sector, as larger organizations are rapidly patenting related technologies to prevent others from using similar technologies, or to ensure that other companies will not patent a certain technology, which could prevent them from using it eventually.

Key Takeaways & Design Considerations

- 3 key 3D printing methods for 3D printed footwear were identified: Fused Deposition Modelling (FDM), Stereolithography (SLA), and Powder Bed Fusion (MJF & SLS).
- The choice for a specific method of printing is dependent on the desired aesthetic, size and structure of the resulting product, as well as the product performance, scale and speed of production, and desired end-of-life of the material.
- 3D printing radically lowers barriers of entry for new and small scale brands to the footwear market, by eliminating much of the upfront investment costs related to product development and stock production.
- While 3D printing of footwear can lead to distributed production networks and a rise of ‘pro-sumers’, this approach is currently not able to compete with the product quality and speed of production of highly specialized, centralized 3D printing factories.
- A platform approach to footwear manufacturing is introduced by Zellerfeld, outsourcing product design and development, ‘democratizing’ access to footwear manufacturing, producing on-demand, and providing product updates. Their goal is to make footwear development and production more akin to uploading a youtube video or releasing an app in the app store.
- An industry shift from towards 3D printing requires a repositioning of companies along the traditional footwear supplychain, and retraining of personnel.
- One of the most important limitations to 3D printing compared to traditional manufacturing methods is the speed of production. Further development is needed in order to reach production times that can support a wider public roll out of printed footwear.
- 3D printing allows for an industry shift towards mass-customization, supported by the introduction of computational design and foot data collection. Such foot data collection brings new challenges with regards to data security and privacy that should be considered.
- Further development of scanning solutions is needed to generate and collect highly accurate foot and gait data, and ensure an accurate physical fit.
- Further research and experimentation is needed to determine how the level of customization and promises around personalized fit affect customer expectations and satisfaction.
- Business development should consider the patents involved in 3D printing for footwear, as well as footwear design related IP.

Environmental Considerations

- A shift to on-demand production is aligned with Dutch Extended Producer Responsibility legislation, as well as new EU regulation that bans the destruction of unsold goods in footwear.
- A shift to 3D printed footwear is aligned with footwear market trends around the reduction of animal cruelty through the creation of products without animal derived materials.
- The recyclability of 3D printed shoes is limited, due to a currently inevitable reduction of product performance without the addition of virgin material.
- Microplastics related to 3D printed footwear can spread through general use and machine washing of the product.
- The environmental footprint of 3D printed footwear is largely made up by energy use. Therfore, there should be a focus on energy efficiency and the use of renewable energy.
- 3D printing allows for the creation of footwear made from a single part and a single material. This offers new opportunities to radically reduce waste at footwear’s end-of-life, through recycling and composting.
- 3D printing in footwear allows for a shift to more transparent and local supply chains of reduced complexity.

05

Company Mission

This chapter describes the mission and vision used for the development of a new circular product-service system for 3D printed children's footwear. This marks the transition from exploration and analysis into the design phase of this project. The mission and vision detail the design's reason for existence and describes what the future product-service system for children's footwear aims to offer and the experiences it seeks to bring about, creating a starting point for the design of future interactions and the final concept of this thesis.

5.1 Mission & Vision

Inclusivity
Circularity
Connection with Oneself
Connection with Others
Connection with Your Environment
Vision Statement

5.1 Mission & Vision

This section describes the core principles upon which the mission and vision of this project are based. Inclusivity, circularity and connection are detailed as core values for the creation of a new circular product-service system for children's footwear. In figure 16, a visual overview is provided of the mission and vision described in this chapter.

Inclusivity

A key building block of this product-service system is inclusive design. Current solutions for children's footwear are often based around standardized shoe lasts, and tying the style of a specific shoe to a specific foot shape, resulting in an inherently flawed model that does not benefit the user and forces people to make compromises between the physical fit and the aesthetic or symbolic value of their footwear. This compromise is even more significant for many children who require specialized footwear solutions, such as insoles with extra support, or semi- and fully orthopedic footwear. In one of the early user interviews of this project, a mother of two young daughters, of which one required special orthopedic footwear, explicitly stressed her desire for new footwear solutions that would allow her child to simply wear something similar to the other children, and her hope in technological advances and new initiatives that would make children's footwear more inclusive. This aligns with one of the reasons for me to start this project. During my time working in footwear retail, I was regularly confronted with the fact that a child might have a preference for a particular shoe style, but the physical fit would not allow it. You would often come to the conclusion that the child had narrow or wide feet. However, I don't think this is correct. A more correct conclusion would be that the shoe is narrow or wide. This would avoid expressing an underlying idea to the child that their feet are not normal. Another instance where I was confronted with the experience of some children with regards to footwear, was when a parent with two young boys came into the store. One quickly asked for the Nike Dunk, a style that was at the peak of its popularity at the time, and something that many children were wearing at school. His brother, however, did not have this choice. He and his parents told me that they would already be happy if there was one style that could fit his feet for casual use, as he usually wore orthopedic footwear. I don't think I have seen a happier customer than that boy the moment he found a pair of Adidas shoes that sufficiently fit his foot shape and had some similarities to the models that other children were wearing at the time.

With the current developments in additive manufacturing and computational design, I truly believe that there is an opportunity to create a new system that does not assume a standard size, and that does acknowledge and include every child, regardless of their physique and footwear needs. The feeling that every user should have is accurately captured in a story told by Simon Sinek about his experience working with one of the Disney 'imagineers'. It tells the story of the opening of a new ride in Disneyland, and a father in a wheelchair with his son, standing in line. The Disney Imagineer states that the reason he works with so much intensity on making the entire experience at Disneyland as easy and seamless as possible for any visitor, is that in any other place on earth, everyone would see a man, in a wheelchair, with his son, but only at Disneyland do we see a father and his son at Disneyland. What mattered to him is that that person never felt like a person in a wheelchair, and that he only felt like a dad with his son at Disneyland (Sinek, 2023).

Circularity

During my first footwear design intership, in 2019, I was tasked with starting a research project about sustainability in the footwear industry. As a a first step, I had taken apart a collection of shoes, piece by piece. I concluded that I truly had no idea about all the resources and materials that went into a pair of shoes, and what actually happened to the product at end-of-life. Upon sharing my findings with my colleagues from different departments, it became clear that I was not the only one. As one does, I started to notice all these ways in which the modern footwear industry was having a negative environmental and social impact. Global supply chains, a lack of transparency and accountability, a lack of knowledge and awareness with designers and users, and the continuous hype and fashion cycles that encourage hyperconsumption all have shaped a modern footwear industry that is unfit for our future. The circular economy framework, as presented by the Ellen MacArthur Foundation, will be used as a central guiding compass that allows the industry to move forward collectively. Three principles form the foundation of this framework:

1. Eliminate waste and pollution
2. Circulate products and materials
3. Regenerate nature

This requires us to be informed and intentional about the design and business decisions we make and the impacts they can have on the system we are part of, throughout every step of the product lifecycle. Being aware of the system is an important addition to our usual way of thinking, as the user we normally zoom in on does not exist in isolation. Moving forward, it is important to be intentional and oscillate continuously between two equally critical perspectives: the user and the system (Ellen MacArthur Foundation, 2022).

Connection with Oneself

Connection is another core principle that I believe to be important for the creation of a new product-service system for children's footwear that effectively addresses the challenges and objectives that were formulated. Three types of connection can be identified: connection with oneself, connection with others, and connection with your environment.

The connection with oneself refers to the connection of a child with their own body and their own mind. The growing connection of a child with their own body and mind is demonstrated by activities of a child in the first years of their life. About four to six months after being born, a baby starts to explore their feet by grabbing them with their hands and wiggling their toes, as they gain more voluntary control over their toe movements. The dynamic process of self-awareness is further demonstrated by the process of self-recognition in a mirror. It generally takes two to four years for children to have a consistent and good understanding of who they are seeing when looking at themselves in a mirror (Rochat, 2003). Children increasingly develop a sense of self and adopt the product into their self-image, and as part of their body (Pugh, 2009).Closed footwear, however, has the tendency to remove your feet from your direct view, possibly inhibiting the connection between a person and their feet. While with children, the feet and toes are generally an integral part of their body language and expression, adults tend to forget to a certain degree that their feet are even part of their body (Leary, 2023). The degree to which this occurs might be related to the visibility of the feet, as well as cultural traditions. One parent stated in an interview that the place where she grew up encouraged the use of open shoes. She stated that wearing flip flops made it easy to touch the earth and feel more free, as you can take the footwear on and off quickly, and move and stretch your feet. She also mentioned her experience with Korean culture as one that is more attuned to their feet and the importance of touching the earth. Another parent that was interviewed stated that she'd had positive experiences with her daughter's foot health and development since changing to more open footwear over the summer. Based on these insights, I believe that a new system for children's footwear should encourage and facilitate the a growing connection between body and mind.

Connection with Others

Connection with others also plays an important role in the design of a new product-service system for children's footwear. Based on previous studies, the interviews performed for this project and personal observations in footwear retail, I conclude that there is often a disconnect between a parent and their child when shopping for footwear, resulting from the different objectives they have in this situation. Where parents generally want to find shoes that fit their requirements in a convenient way, children tends to be more interested in the possibilities for play and socializing with other children. This can lead to frustrations in both parent and

child during the process of finding children's footwear in a physical store. The majority of parents that were part of this study noted high adoption rates of online shopping behavior for children's footwear. Online shopping has either fully substituted or at least supplemented the offline footwear buying process. In addition to the greater variety of options available online, it was stated that the online experience allowed for a calm browsing experience, because the child was not included in this process. Analyzing the design of a large variety of online footwear retailers for children leads to the conclusion that online stores for children's footwear largely look and function the same as those for adults. This is in contrast to many physical retailers for children's footwear that have turned stores into colorful places that resemble playgrounds, and encourage exploration and movement (see appendix A). Whereas offline stores invite parents and children to visit together, online stores seem to be designed for parents alone, either as a result of or resulting in parents buying footwear alone, largely without any consultation of the child until the shoes arrive at home.

Such footwear purchasing behavior can be detrimental for a number of reasons. First of all, it takes away the possibility of the child to have input into the decision-making process with regards to the fit and style of the shoe, to a large extend. Visiting a physical store allows the child to try on a wide variety of shoes with different fit options, in order to find some sort of optimal choice. When shoes are purchased online, this choice is often limited to the amount of pairs that are ordered, which is often one pair of shoes that is kept if it fits sufficiently well. Some parents might increase the options for their child by purchasing four pairs at most, with the two or three other pairs of non-selected shoes being returned, as I learned through informal conversations with parents. The same principle is true with regards to style, as parents will either choose the style of the shoe completely or provide a limited selection which the child can choose from, discouraging exploration by the child itself. At a young age, below four or five years old, this might not be too detrimental, but as the child grows, so grows the desire to be heard and their opinions to be taken seriously by their parents. It is important for a developing child to be able to assert their preferences, develop a sense of autonomy, identity and responsibility, and learn from the decision-making process of their parents by observing and increasingly participating in a form of co-consumption (Sokol et al., 2013). Therefore, I believe that a new system for children's footwear should encourage and facilitate the connection between parent and child in the process of choosing shoes.

Connection with Your Environment

The third category of connection that is considered relevant for this project is that of an individual with their environment. As formulated in the mission statement, the goal is to build a footwear industry with respect for people and planet. As a result of globalization, mass production, complex supply chains and consumer culture, people have become increasingly detached from the origins and production processes of their products, which includes footwear. During the conversations with parents, it was noted that some parents were concerned about the environmental and social impact of footwear consumption. Poor labor circumstances, child labor and the generation of waste at the product's end-of-life were considered especially concerning. However, even when the parents expressed genuine concerns about these topics, and were personally or professionally involved with sustainability or circularity, these concerns still did not significantly affect the footwear choices for their children. A common problem for parents was accessing and understand sustainability information of shoes. Additionally, convenience, aesthetics, availability, quality and price where overall more important factors in the decision-making process. During an informal conversation with one parent with a son of twelve years old, it was noted that the detachment of her child to the origin of products was starting to decrease, as schools started to provide more education to children about manufacturing and labor circumstances associated with the products we consume. A new system for children's footwear should align with this development and encourage and facilitate a stronger connection between the users and the environmental and social impact related to the product they use.

Figure 16: Mission and vision statement

Vision Statement

The previous elements have describe how a circular product-service system for 3D printed children's footwear should be created. These elements are part of a greater future vision that can be summarized in the following statement:

"I believe in building a footwear industry that supports healthy and confident living, with respect for people and planet."

This mission statement is directed towards the footwear industry, as I believe that the footwear industry needs to be fundamentally reshaped in order to be future ready and serve the needs of people and our environment. Health and confidence are an abbreviated way of addressing the physical, mental and psychosocial functions of footwear. Additionally, I believe that it is important to empower parents to feel confident about their parenting capabilities. Especially new parents can experience uncertainty and anxiety around determining the right footwear to buy for their child. A new system for children's footwear should focus on allowing both child and parent to feel great. Even though this project will focus on children's footwear, the mission statement itself does not directly mention children or parents. Reason for this is that the goal is to enable lifelong healthy and confident living. Rather than creating something for children alone, this project seeks to provide solutions that set children up for health and confidence in the rest of their life.

06

Product Design

This chapter presents the design exploration that was done around the physical product, as a starting point for the proposed PSS. First, further explanation is provided around the choice for fully printed children's footwear. The second section provides a visual overview and description of a first collection of 3D printed children's shoes that was developed for this thesis. Finally, this chapter details the testing that was done with end-users to provide new insights for further development of the product and system.

6.1 An Exploration Into Fully Printed Children's Footwear

Towards Circularity
Variety
Personalization

Key Takeaways & Design Considerations

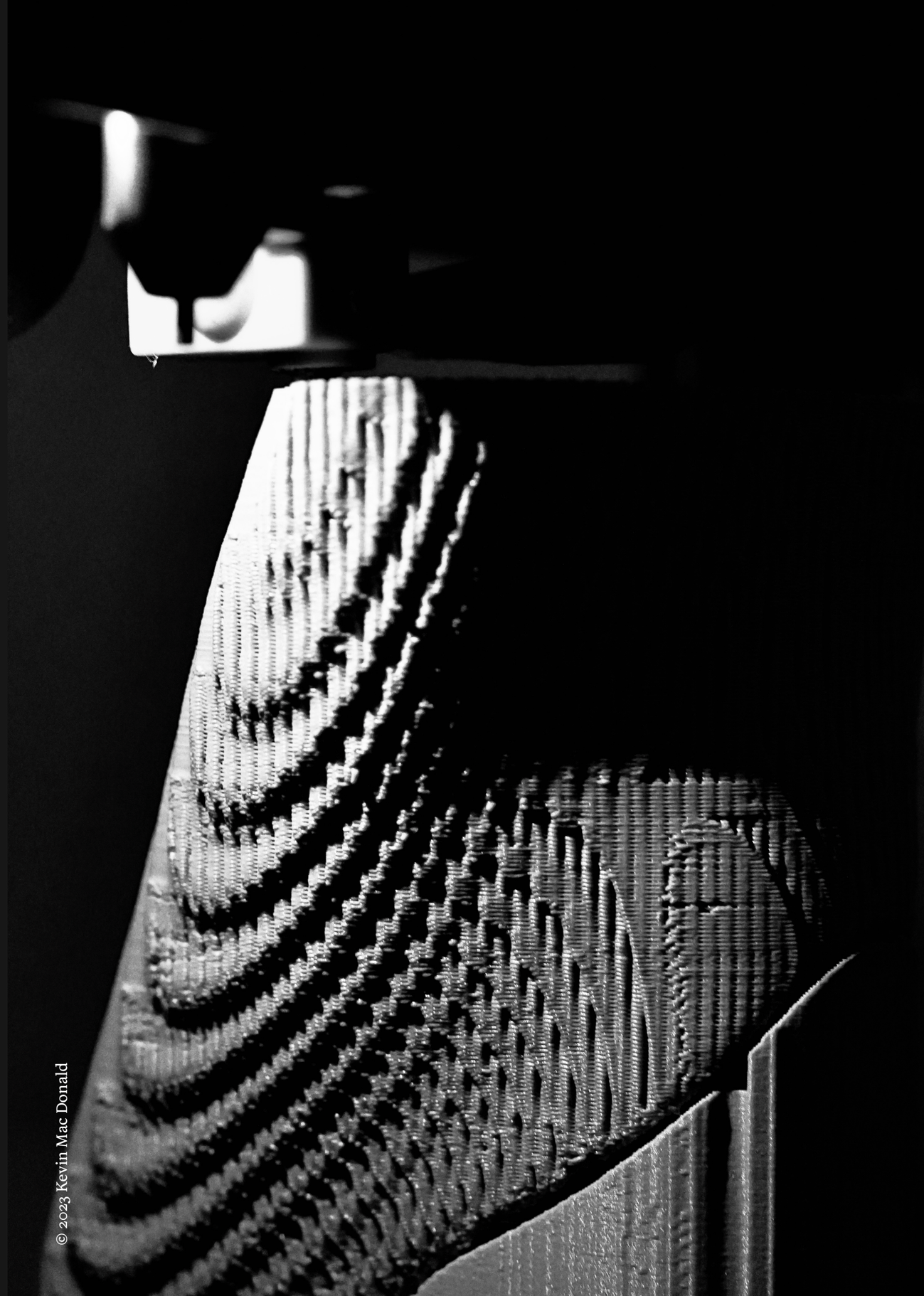
6.2 Designing a Collection

Concept Design
Prototyping

6.3 User Testing

Method
Results
Discussion

Key Takeaways & Design Considerations



6.1 An Exploration Into Fully Printed Children's Footwear

This section provides an introduction to the product development part of this thesis. It seeks to provide a deeper understanding of the design choices that were made in the creation of the product part of the PSS, as well as the entire system.

Introduction

The creation of a circular product-service system for children's footwear in this thesis involved the development of three core parts: a physical product, a retail experience and additional services. These parts were developed simultaneously and co-evolved throughout the project. This chapter presents the physical product design as part of the system and describes the considerations that have led to a predominantly mono-material approach in the context of this project. The experience and service design are detailed in the following chapter.

Towards Circularity

Chapter 4 details the current state of 3D printing in the footwear industry, and presents the implications and considerations related to the shift away from traditional footwear manufacturing. In 2019, I was first exposed to the concept of 3D printed footwear during an internship at a local footwear company, which involved the disassembly of shoes (see figure 17) and the creation of a roadmap for sustainable footwear innovation. This roadmap described three key steps in the creation of more sustainable footwear: 1) materialization, 2) modularity, and 3) mono-material. Sustainable materialization provides a first step for improvement, as shoes are traditionally made with as much as sixty-five discrete parts, made from a variety of materials, and relying on complex supply chains and networks of manufacturers (Cheah et al., 2013). In order to explore the possibilities and challenges for implementation, I have spent the past two years doing extensive research on current production methods, sustainable material suppliers and the development of sneakers with footwear manufacturers in Portugal. As discussed in chapter 4, the large investment costs, and the complexity of the footwear supply chain, as well as the product architecture of footwear, make it very challenging for individuals and new brands to create a product that is truly more sustainable and bring it to market. At the same time, I saw rapid innovation happening in the fields of modular and mono-material footwear development, facilitated by the evolution of

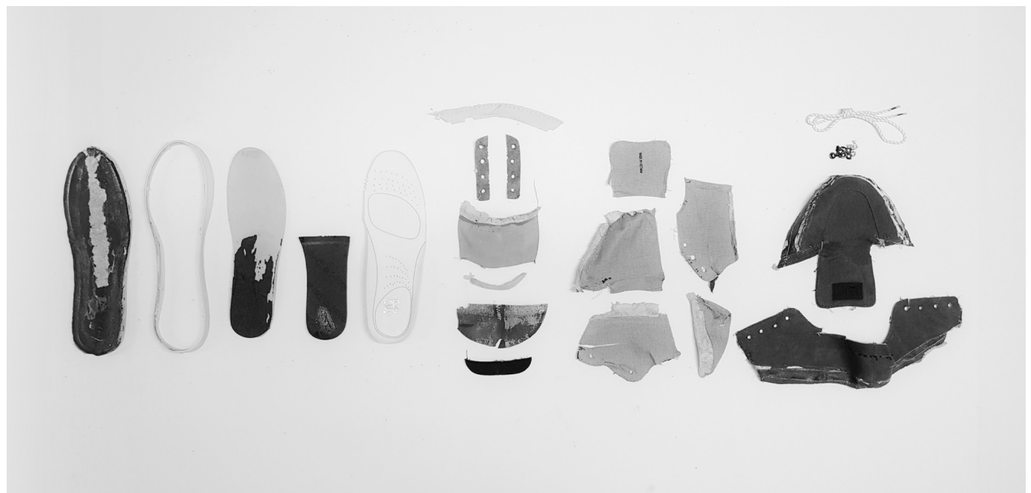


Figure 17: Sneaker disassembly

Figure 18: Aguahoja (Oxman, 2021)

local and additive manufacturing methods, such as 3D printing and 3D knitting. As we start to move into a future where the industry embraces sustainability and mass-customization, there is an opportunity or even a need for radical change with regard to the physical manifestation of footwear. While previous product development and research have shown me that it is easier for established, medium to large scale companies to invest in sustainable materialization of their existing products, due to economies of scale, I believe that small scale, innovative footwear startups have a unique opportunity to embrace these new technologies and create products that are radically different from what people currently have access to and what existing supply chains are able to offer.

Towards A Grown World

In relation to the current state of design, Neri Oxman stated: "At least since the Industrial Revolution, the world of design has been dominated by the rigors of manufacturing and mass production. Assembly lines have dictated a world made of parts, framing the imagination of designers and architects, who have been trained to think about their objects as assemblies of discrete parts with distinct functions." (TED, 2015). She expresses nature's lack of homogeneous material assemblies, and its preference for systems that gradually vary in functionality by varying material properties. Looking at the current product architecture of most footwear, this contrast is easily found. A complex assembly of components that has not been designed for end-of-life processing is at the root of many challenges that the footwear industry faces as it tries to move forward. With the introduction of 3D printing and computational design in footwear for end-users by companies like Zellerfeld, we can start to imagine a world in which shoes become a true extension of the body, rather than a restricting attachment - a future where products are grown, rather than assembled. By using high resolution scanning technology to capture high quality data about the user's body, a product can be

made that has this nature-like gradual variation in functionality. Upper, padding, lining, insole, midsole and outsole are one. And when it is time to discard the product, the entire product can be processed at once, without disassembly steps that would significantly increase the energy, cost and time associated with post processing, effectively increasing the effectiveness and efficiency at which a material can be recirculated through the system.

The design philoshophy presented by Oxman is embodied by Aguahoja: a collection of structures digitally designed and robotically manufactured from some of the most abundant biopolymers on our planet (see figure 18). Another exploration of this philosophy is presented by NEFFA, a Dutch startup developing a new approach to working with mycelium, a bio-based material that has become popular throughout the fashion industry for its leather-like material characteristics. Rather than growing mycelium, turning it into sheets for cutting and sewing, NEFFA aims to make use of 3D printing technology to create molds in which mycelium can be grown directly into its final product shape directly (Mycotex, n.d.). Referencing the the Butterfly Diagram (see figure 19) by the Ellen MacArthur Foundation (2013), such an approach would bring us closer to a future were all things technosphere are designed as if they are part of the biosphere.

Challenges in Circularity

Choosing for a mono-material, 3D printed construction of one part brings along several challenges related to the circularity of the system. As described in the technocycle of the Butterfly diagram proposed by the Ellen MacArthur Foundation (see figure 19), the goal is to keep managing resources sustainably and maintain their value effectively and efficiently. Extended product use is preferred over recycling, as recycling requires greater amounts of energy and material resources to maintain the value that is provided by the product. Extended use of a product can be seen in two ways: the product can be used for a greater amount of time by the same user, or the same product can go through multiple different users. The path that is chosen has a direct impact on the design of the physical product, as children's footwear that is made for extended use requires a design that facilitates the physical growth of a child's feet. This could be achieved by the implementation of socks or insoles, for instance, which can be removed as the child grows to provide room for the foot. This method is, however, limited by two interacting factors. First of all, there is currently a limit to how much a shoe can physically grow with the user. The addition of insoles or socks in varying thickness will generally provide an extra half size of growth room for the foot. Additionally, the replacement of shoes is not only related to the growth of the child. The physical wear and damge to shoes, as well as the change in seasons are additional factors that drive the replacement of children's shoes. Therefore, the amount of growth that is built into shoes should be carefully weighed against the expected rate of replacement. Moreover, if a shoe is made to grow and be used by the same user for an extended period of time, this will likely result in more wear and breaking down of the product at end-of-use, making it less suitable for reuse, for health and aesthetic reasons. This could be counteracted by adopting a modular design that allows for the exchange of certain parts, such as the insole and outsole to counteract the shaving and compression of the sole. However, while effective at improving the aesthetics and preventing foot development problems related to the child's developing gate, this also becomes a highly complicated construction rather quickly.

Material Innovation & Modularity

The choice for a mono-material, 3D printed approach for children's footwear can also be motivated by the competitive value that could be achieved with a focus on material development, rather than a focus on modularity. Increasing the functional product lifetime by making it more durable can be achieved by exchanging parts that are worn out, but it can also be achieved by using printing materials, 3D printing techniques and footwear designs that promote greater durability of the product in general. I believe that a focus on material innovation will likely yield greater returns and provide a more interesting competitive position over time. Even if the goal is not to drive competitiveness but go the open-source route and make the material publicly available, this will likely have a greater impact on the industry moving towards a more circular

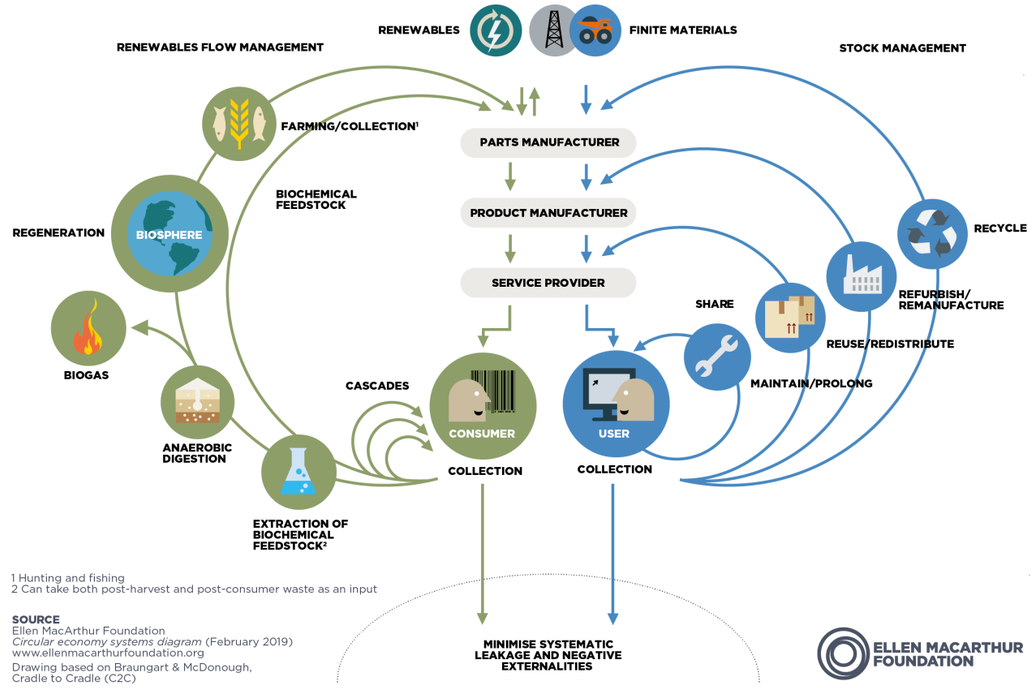


Figure 19: Butterfly diagram (Ellen MacArthur Foundation, 2013)

and sustainable model. When we keep in mind that the end-goal is to achieve an envisioned future where products are grown, rather than assembled, allowing us to find a way in which all things technosphere are designed as if they are part of the biosphere, a great focus on 3D printing and material innovation is desirable in my opinion. Companies like Balena are already developing a new generation of 3D printing materials to replace non-compostable and synthetic plastics, with a first proof of concept already delivered in the form of a 3D printed slide and an upcoming partnership announced by Vivobarefoot (2024). A final important challenge that could benefit from such development of natural materials is that of the microplastics that are commonly generated through the use of footwear, as plastic particles are removed from the sole with each step or each wash, leading to pollution of the environment.

Recirculation Infrastructure

In order to facilitate the recirculation and reuse of 3D printed children's footwear, a system is necessary to collect and assess used products. Such a system could be based on a similar deep learning approach that is currently being investigated for optimization of print speed and quality at Zellerfeld. In this system, a camera captures the print in real time and a computer constantly compares the live print to a digital version of the shoe to provide a form of automatic quality control (Kreutz et al., 2022). In 2022, Nike introduced a sneaker cleaning robot that was programmed to identify places of wear and tear on a selection of their shoes, based on a similar technology (Nike, 2022). If such a system were to be deployed for the purpose of identifying locations of wear and tear on a pair of 3D printed shoes after use, this would provide an efficient way of determining which shoes are ready for reuse, and which shoes should be recycled. Additionally, collecting such data would provide valuable insights into product performance. Combined with the flexible nature of on-demand manufacturing and the availability and direct control over the 3D model, this could lead to rapid product iteration and improved quality.

Variety

Functionality and Aesthetics

As stated in the initial brief for this thesis, one of the key objectives of this project is to deliver a system that removes barriers for families to get the footwear they want, without needing to compromise on the child's foot health and lifelong mobility. This means that a new product-service system for children's footwear should be able to provide products that both align with the customer's taste or style, and with their changing physical footwear needs.

At any given time, most children have a small collection of shoes for functional reasons. A combination of sneakers, boots, wellies and formal shoes is common in fall and winter, while in spring and summer, children might own a pair of sneakers, slippers, ballerina's and sandals. Light colored shoes might be complemented with darker shoes from tough materials that are more weather resistant. Certain shoes are mainly for casual use, while others are used for more formal situations or sports activities. Different footwear is used for different situations and environments, and a new product-service system for children's footwear should ideally be able to fulfill these different footwear needs in a way, as this would allow the system to physically grow with the user and provide them with appropriate footwear throughout the year.

In addition to physical growth and functionality, it is important that the system is able to grow with the changing identity and social needs of the user. The same shoes that a young girl loves at five or six years old, might be actively avoided once the user is nine or ten years old (Marshall, 2010). Or the style of children's shoes that is popular among parents one year, might not be so desirable the next year. Footwear trends are hard to predict, and to increase the chances of maintaining an identity and social fit with ever changing desires from users, a system should be designed that is able to offer a wide variety of options and is able to move dynamically along with the changing demands from users.

A Desire for Variety

The desire for variety in footwear options was further confirmed through the empirical research described in chapter 3. As offline shopping was often replaced with online shopping for children's footwear, partents expressed that the greater availability of options was a key driver of this shift in consumption behavior. Likewise, previous research notes that children are also likely to value a variety of options, allowing them to find option with the best identity and social fit. Marshall (2010) quotes a girl, aged 12: "I like Nike because they are cool and because they make a lot of shoes in variable styles". This desire for variety is further supported by Robbins' framework of 'six human needs', and previous research that found that the desire to choose new alternatives over more familiar was so strong that it influences people to switch from their favorite, trusted products to ones that they like less, simply because they are different (Team Tony, 2021; Solomon, 2013).

An Analogy for Choice

While people have access to a large amount of footwear options, there is often a need to compromise on fit. Especially if a child needs wide or narrow fitting shoes, finding a pair of desirable shoes can be accompanied with feelings of frustration and exclusion. To generate the greatest opportunity for every user to find options with a great physical, identity and social fit, it is therefore required to deliver a system with a wide variety of choice for each user. The decision for this approach and imagined interaction could best be explained with the analogy of someone with a dairy free diet at a local ice cream shop. Rather than adding a couple of dairy free options to the existing menu, which could deliver a feeling of restricted choice, exclusion and the possible need to make a compromise between taste and health, the goal is to create the equivalent of a completely dairy free ice cream shop, where you already know that all options are aligned with your physical needs, and you have complete access to all available options, just like any other customer. The objective is to deliver every customer with a feeling of inclusion, belonging, excitement and with the confidence that whatever option they choose, they can be sure that it is good for them.

Figure 20: Nike ISPA Link (Santiago, 2022)

Limitations of Modular Footwear

In this regard, a mono-material, fully 3D-printed approach will likely yield greater results, as it radically reduces the complexity of the product architecture and supply chain. Looking at the product and business model from Zellerfeld teaches us that a set of physical product design constraints, on-demand, additive manufacturing of a mono-material shoe from one part allows for widescale collaboration and outsourcing of footwear design. A modular design, on the other hand, limits the amount of variety and customer fit that can be achieved within the same amount of time for a couple of reasons. In recent years, I have followed and actively engaged in the design and development of modular footwear. What I realized is that the opportunities for modular footwear are restricted, due to the amount of pressure and movement that the product is exposed to through use. This causes a lot of problems and limitations for the connections that can be used between the different parts of the shoe, and makes it hard to create a modular product with desirable product performance.

Additionally, most modular footwear has a distinct look. It is often constructed of a knitted sock in some type of molded or printed foam or rubber cage construction, like the Nike ISPA link that was revealed in 2022 (see figure 20). Such a construction does allow for the creation of multiple variations by providing a variety of socks and soles that could be mixed to create a various aesthetics, but the greater complexity in product architecture also limits the possibilities for radically different shapes and styles. As a result, it also forces product design and development to be done in-house, rather than through collaboration with a large variety of designers, as Zellerfeld is doing currently. Another benefit of a fully 3D printed shoe of one part is that the supply chain is much less complicated than that of a shoe consisting of multiple parts. Less coordination between different suppliers, and direct control over the design and end-product are significant advantages for a footwear startup that does not have economies of scale with their suppliers and wants to be adaptive to changing market conditions. There is no need for creating product stock or tooling, other than the 3D printer and possible post-processing machinery.

Pitfalls of Choice

As powerful as the Zellerfeld model is in creating a huge variety of designs in an extremely short amount of time by leveraging the crowd to deliver new designs and 'democratizing' access to footwear production (see figure 21), potential pitfalls also arise from this strategy. A risk for a system that offers a wide variety of options and large freedom of choice is that it might cause choice paralysis and dissatisfaction (Schwartz, 2016). As the number of options grows, users of the system might have a hard time deciding between the different styles, and even if they are able to make a decision, they might still be less satisfied with that decision as they wonder if they have made the most optimal choice. One parent that was interviewed for this project noted that she had been using a clothing and footwear subscription service for her children to deal with the overwhelming amount of clothing and footwear choices. Every month or every couple of months, she would receive a box filled with clothes and footwear that she did not select by hand, but they did meet the criteria that she had provided beforehand. During an informal conversation with another parent, it was noted that a good filtering system was critical for her online buying experience for children's footwear. It was especially important that the filtering system was easy to use, and that it was actually able to show all the options that fit her criteria, without leaving any good options out. Therefore, in designing a future product-service system for children's footwear, availability of options needs to be balanced with an experience that makes it easy for people to make a decision, and make users feel like they have made an optimal decision, especially as one of the traditional selection criteria, physical fit, no longer plays a role.

Figure 21: Fully 3D printed shoes offered by Zellerfeld (Schwaar, 2023)

Personalization

Levels of Personalization

The availability of high-quality 3D models and the collection of data on the user's foot dimensions and fit preferences makes it possible to create extremely personalized footwear in an efficient manner. As stated previously, personalization of footwear can fall into one of four categories, as described by Boer et al. (2004) and Salles (2011):

1. **Design Customization** – the first level of personalization, allows customers to select aspects related to colors and materials or to small details like name printing.

2. **Size and Fit Customization** – the second level of personalization, offers a shoe built to specific dimensions (e.g. width) and the feet of the customer, in addition to the parameters offered at the previous level.

3. **Best Fit Approach** – it permits customization by identifying the 'last' style combination that is the best approximation of the customer's feet dimensions and requirements.

4. **Custom Made Approach** – this more complete level of personalization allows the shoe to be manufactured meeting both dimensional and functional requirements.

The level of customization that is offered to people has direct implications for the circularity and customer satisfaction of the system. The degree of personalization that is available for users determines the end-of-use solutions, since a fully personalized shoe would not be fit for any other person than the original user. Therefore, recycling or composting are a likely options for end-of-use after the first user. However, limiting the degree of personalization in physical fit to a 'best fit approach' or 'size and fit customization', as currently done by Zellerfeld (see figure 22), might create possibilities for reuse of products, as new users could, based on their foot scan, be matched with existing footwear that matches their requirements. Additionally, the possibility for reuse will likely vary based on the age, speed of foot growth and activity levels of the child. Through the empirical research described in chapter 3, it was found that foot growth is the primary reason for replacement of footwear for young children. However, as children grew older, foot growth started to slow down, and the child became more active. Therefore, the wear and tear of a shoe would become an increasingly frequent reason for replacement. Based on these insights, an assumption could be made about an age until which most shoes that are returned to the company at end-of-use can possibly be reused by another user, for one or more rounds, while after this age, it is more likely that footwear will be damaged and so worn out that they are more likely to be recycled. The likely possibility for reuse of young children's shoes offers an important opportunity with regard to manufacturing limitations related to 3D printing. The higher replacement could lead to problems as the speed of manufacturing with 3D printing is very limited, compared to traditional manufacturing methods like molding. By reusing and keeping the product in circulation through different users, the fast replacement rate of young children's footwear could possibly be accommodated for, while also reducing the price for the end-user, as the cost could be covered by several consecutive users.

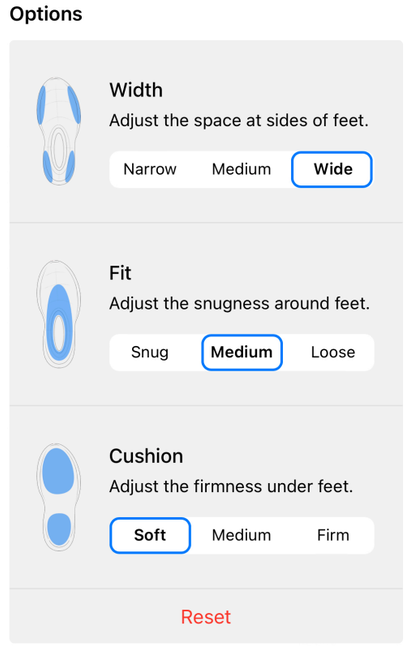


Figure 22: Zellerfeld customization options (Zellerfeld, n.d)

Design Customization

One case in which the personalization level of ‘design customization’ could possibly generate significant added value for users is that of a child’s first pair of shoes. For many parents, their child’s first pair of shoes is an important milestone, and it is often the only pair of shoes that is held onto by parents for the sentimental value it holds. In the design of a product-service system for 3D printed children’s footwear with a focus on healthy foot development, this emotional value should not be overlooked, as it could become an important reason for new parents to buy into the system initially. 3D printing and on-demand manufacturing make it possible to create personalized products in a cost-efficient way, resulting in a first pair of shoes carrying personal information like the name of the child or the date on which the first pair of shoes was made, to commemorate and celebrate this important milestone in the journey of footwear and lifelong mobility. Of course, such personalization does not make this product fit for reuse purposes. The goal here, however, is to stress the importance of this milestone with parents, by encouraging them to hold onto this pair for the rest of their lives, as tangible and meaningful start to their child’s footwear journey. Moreover, empirical research in chapter 3 and informal conversations led to insights around gift giving behavior around children’s clothes and footwear, and highlighted the business opportunity to use such initial product exposure to bring people into the new system. Further research is needed to determine how the aesthetic customization of a child’s first pair of shoes might affect the degree to which such footwear would considered a desirable gift.

Custom Made for Special Needs

Even though personalization at the level of ‘custom made approach’ might not become available to the wider public, the structure of the system could potentially lend itself to such personalization in the future to also enable children that traditionally are confronted the most with the limitations of footwear choice and the compromises between physical, identity and social fit. To this end, collaboration with podiatrists would be necessary to generate products that are fully aligned with the body of the child and its special footwear needs. Such a program would incur significantly higher costs for the user, compared to regular footwear that is bought through the system with a personalized fit and size. However, such specialized footwear is traditionally also significantly more expensive than regular children’s footwear, and the relative cost increase of fully customized 3D printed footwear is likely to be much less significant, compared to that of traditional footwear. This is due to the lack of tooling and manual labor that is traditionally necessary for the creation of semi- and fully orthopedic footwear.

Key Takeaways & Design Considerations

- A fully printed and mono-material approach to footwear is aligned with the vision of moving towards a grown world, rather than an assembled one.
- Further innovation in manufacturing and materialization is needed to create products that are effectively part of the biocycle.
- The extension of the functional life of children’s footwear is limited due to physical growth that occurs in children’s feet. Additionally, the replacement rate is codependent on and should be mediated with other factors influencing the replacement of footwear, such as seasonal changes, changes in style preferences, and physical wear and tear of the product.
- A modular approach to footwear has been proven to significantly increase the complexity of the product architecture and supply chain necessary for the realization of the product.
- A fully printed approach is preferred over a modular approach to children’s footwear within the context of this project, as it provides greater opportunities for the efficient creation of a large selection of style options.
- Investing in material innovation and design optimization is preferred over a modular approach for business strategic reasons, and the general industry encompassing impact that such innovation can have.
- Investment in infrastructure for end-of-life collection, processing and product performance assessment is required.
- The design of the system should consider pitfalls related to offering a large amount of options to users, as there is a risk of choice paralysis and reduced customer satisfactions. Careful curation of styles and easy browsing and selection tools should be designed to help users to make a choice.
- The level of personalization of physical fit and customization of visual appearance should be carefully considered, as these will directly impact the end-of-life options for used footwear.
- The level of personalization of physcial fit and promises thereof should be carefully considered, as it might strongly affects customer expectations and, ultimately, customer satisfaction.
- Further research is needed to assess the desirability of aesthetic customization options in relation to a child’s first pair of shoes, and the desirability of such products as a gift.

6.2 Designing a Collection

In order to explore the current possibilities for fully printed children's footwear, a first collection of shoes was designed and prototyped. This chapter details the creation of this collection.

Concept Design

The collection that was designed for this thesis includes five different styles. These styles were designed in order to represent a variety of existing and popular children's footwear categories, and test how these styles could be translated into fully 3D printed and functional objects, with desirable aesthetic value. The following pages provide a visual overview of the styles that were created. Empirical research and existing literature suggest that sneakers and wellies or rain boots are currently the most frequently used footwear styles for children (Hodgson et al., 2021). Figure 23 shows a rain boot style, while figure 24 and 25 show designs that are more akin to modern sneakers. The shoe that is shown figure 24 was created to embody a more sportsy silhouette with a thicker sole and flowing lines, while the model that is presented in figure 25 represents a more classic silhouette, taking inspiration from popular skate styles like Vans Old Skool and Nike Blazer. A barefoot style was added to the collection, as this style of footwear has become increasingly popular for its health proposition and the promise to allow your feet to grow stronger (see figure 27). Barefoot features like a thin and highly flexible sole have already been an important feature of high quality footwear for very young children, as it allows a child's foot and gait to develop naturally. Finally, a ballerina style was added (see figure 26), as this style is distinctly different from the other styles and has remained popular in various regions around the world and for a variety of occasions.

In the design of each style, a variety of use cases and desirable product characteristics was considered. By varying the wall thickness and texture of the product, varying product characteristics could be achieved inside a product consisting of one material and printed as one part. In order to prevent significant wear from happening, a close wall texture and greater wall thickness were applied in areas where high amounts of wear are expected through regular child activities, most notably the heel, toe and bottom surface area of the shoe. Additionally, playing with the closed and open wall texture allows for the shoe to have increased breathability or water proof characteristics. In case of the rain boot style, a mostly closed wall design was chosen in order to prevent water from entering the shoe in wet conditions. In order to increase ease of use, an open texture was applied in the collar area where the foot enters the shoe, allowing for increased flexibility. The other styles were designed for dry conditions and with greater breathability in mind. Next, various patterns were created to fit the style of each shoe and provide the necessary traction in order to create a product that is safe to use in dry and wet conditions. In addition to delivering different product characteristics, the variation between a smooth closed wall surface and an open wall texture provide a very distinct product appearance that is uniquely possible through the use of 3D printing. A final aeshetic addition to the design of the barefoot style was the addition of a name and the date of product manufacturing (see figure 28). This could was designed as an additional customization option to prevent increased emotional value for the product. Such product customization could especially be valuable for a first pair of children's shoes, as these are often kept by parents for its sentimental value.

The entire collection of 3D printed children's shoes was designed using Blender and Rhino 3D modelling software. A combination of polygon based subdivision modelling and nurbs modelling was used to achieve the variety of shapes that is found in the different footwear styles. The variation in closed and open wall texture was achieved directly in Cura, a free and open-source printing software developed by Ultimaker. This texture was created by varying the wall and infill print settings. By slicing the model in Cura and exporting the resulting gcode into prusa, the gcode was eventually turned into a model that was rendered in Keyshot, a 3D rendering and animation software.

Figure 23: Render of LUCA 'Nelly'

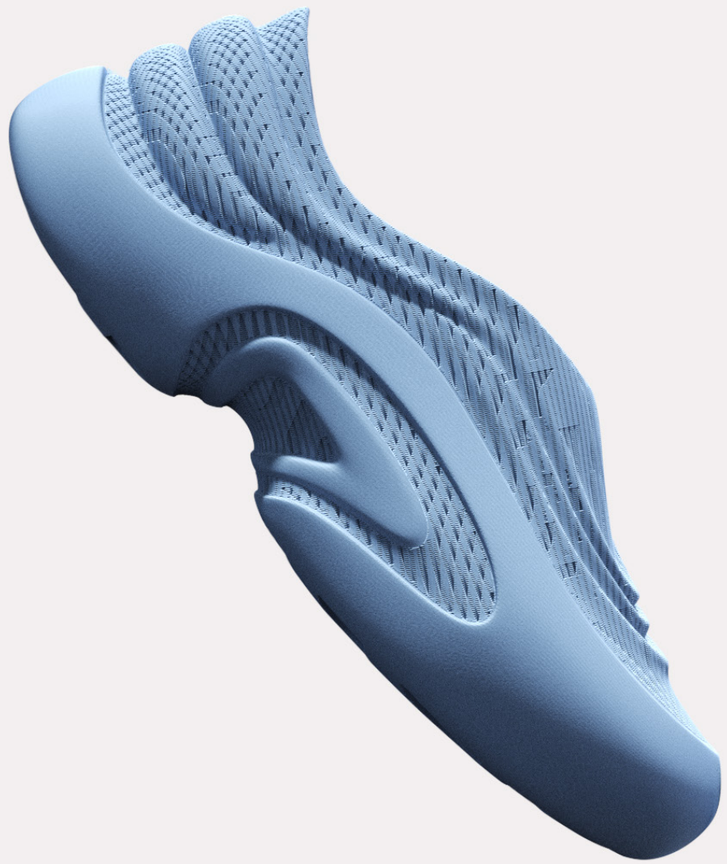


Figure 24: Render of LUCA ‘Reef’

Figure 25: Render of LUCA ‘Sleek’

Figure 26: Render of LUCA ‘Wander’

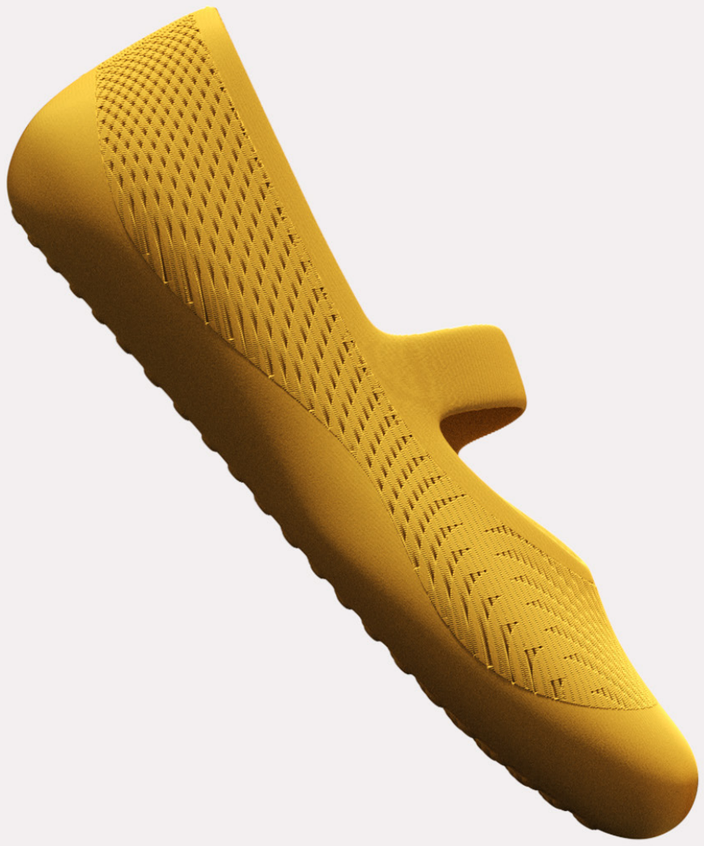


Figure 27: Render of LUCA ‘Ballerina’

Figure 28: Render of first shoes with aesthetic customization

Prototyping

In order to test the printability of the different footwear styles that were designed for this project, a series of physical samples was printed on a low-cost desktop FDM 3D printer. First, a series of non-functional models was printed in various colors using PLA as a material (see figure 30 and 31). These models are useful to inspect the product dimensions and shapes in hand, in a way that is cost- and time-efficient and allows for quick design changes that can directly be applied to the digital model. Additionally, a variety of models was printed using the same printer, but with Filaflex Foamy (see figure 29). Filaflex Foamy is a recently released TPU based filament with foaming capabilities, allowing the creation of products with varying shore hardness. Through trial and error, print settings were found that provided a desirable prototype made from a foam rubber material that is lightweight, flexible and stretchy. Moreover, the use of Filaflex foamy resulted in a product with a product that is relatively soft to the touch, compared to materials like non-foaming TPU. Compared to PLA, printing with flexible materials like (foaming) TPU offers significant challenges. Most notable is the prevention of humidity. As TPU is a highly hygroscopic material, a slight increase in the humidity of the print environment can cause significant problems, such as clogging and various printing quality issues (Recreus, 2021).

To combat these issues, various interventions were tested to improve the print quality of the flexible prints. By regularly ventilating the room in which the printer was placed, using a small electric air dehumidifier, and raising the room temperature, humidity levels were eventually controlled. In order to create a successful print, further interventions were needed to preserve the filament before and during each print, and prevent moisture from being absorbed. Filament was stored in a controlled environment with sylica gel, and it was kept inside an electric filament drying box for the entire duration of the print. Depending on the amount of material required, each of the shoes made with Filaflex Foamy took between 24 and 48 hours for a single shoe (see appendix C). Compared to prints with PLA, this is about twice as time consuming as a result of the difference in optimum print speed. The various surface patterns were created by varying the infill and wall print settings, which also resulted in products with different flexibility.

Figure 29: 3D printed prototypes made with foaming TPU

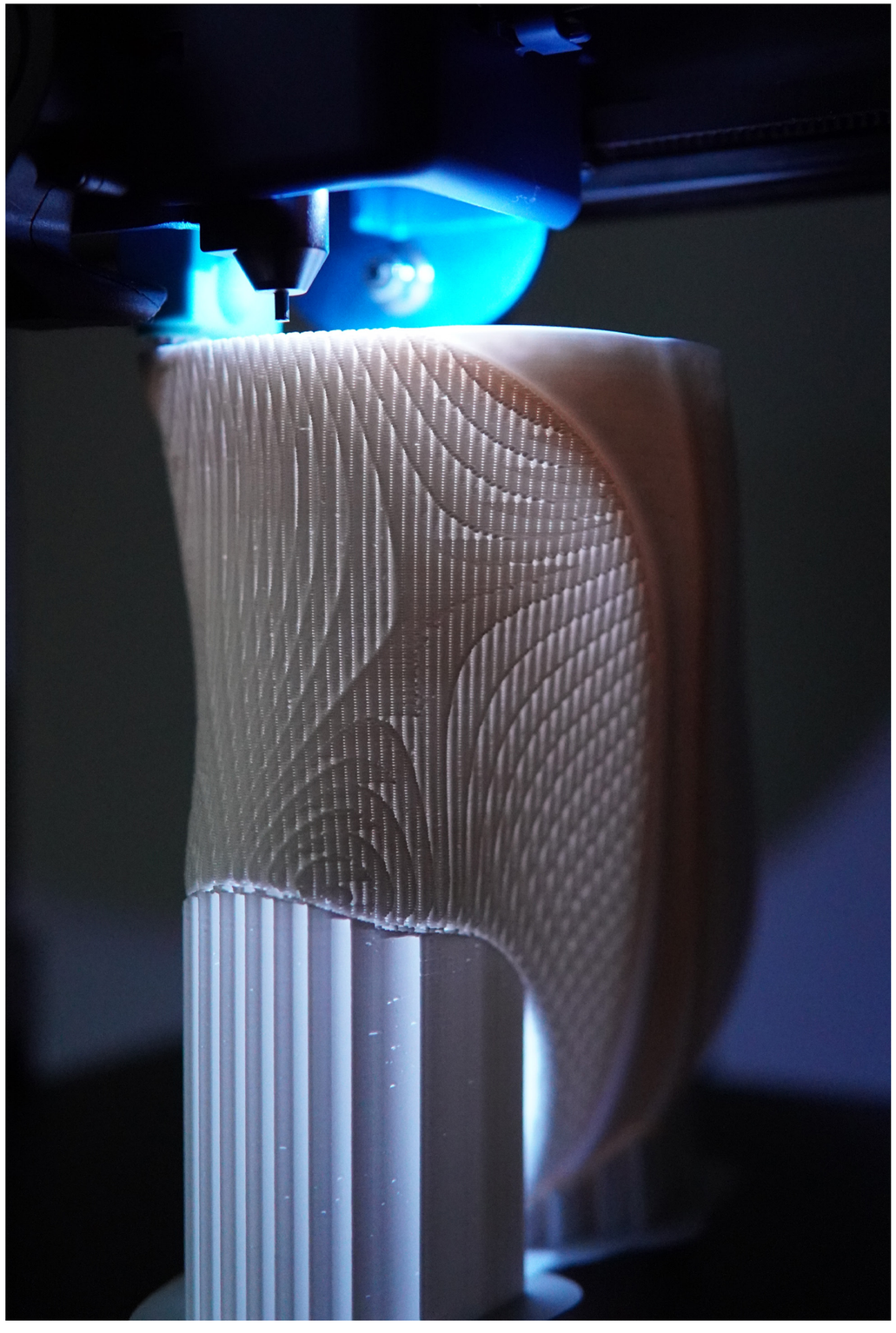


Figure 30: 3D printing process of PLA prototype of LUCA ‘SLEEK’

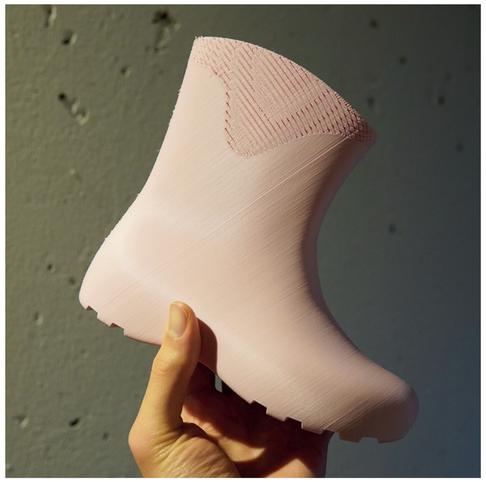








Figure 31: Overview of 3D printed prototypes made from PLA

6.3 User Testing

This section provides a detailed explanation of the user testing that was conducted during this thesis with regards to the physical product design as part of the PSS. The research method, results and discussion of the results has led to key takeaways and considerations for future development.

Introduction

In order to assess the current perception of fully 3D printed children's footwear and identify areas for improvement before market introduction, a series of interviews was organized with parents of children up to twelve years old. These interviews have provided important insights with regards to the current perception of fully 3D printed shoes by the target group, providing clear guidelines for further product development in order to further meet their needs.

Research Method

Research Design

The aim of this study was to gain an in-depth understanding of the initial reactions and feedback based on visual representations and verbal description of the collection of fully 3D printed children's shoes that was developed within this thesis. In order to collect rich data that could inform further design iterations, semi-structured qualitative interviews were conducted with possible end-users, and by use of an interview guide (see appendix D). This particular interview structure was chosen as it allowed for a flexible and exploratory approach, with the possibility for the researcher and participant to further elaborate on topics that might arise during the interview and are considered of interest to the study. Seven formal interviews were conducted, each with a duration of thirty to ninety minutes, and with a parent of at least one child up to twelve years of age. Every interview was recorded on a dedicated audio recording device, and analyzed in order to identify common themes. Six out of seven interviews were conducted in dutch, while one was conducted in english. For readability purposes, dutch quotes in the results section are translated from dutch to english by the corresponding researcher and using free online available translation tools.

The following research questions were formulated for this part of the study:

RQ1: How desirable do parents consider the aesthetic of fully 3D printed children's footwear?

RQ2: To what extent do parents consider fully 3D printed children's footwear capable of physically supporting their child's activities?

RQ3: To what extent can aesthetic customization of fully 3D printed children's footwear increase the perceived value of a child's first pair of shoes?

Sampling & Communication

Participants were found through the personal network of the corresponding researcher and through snowball sampling. This study included a variety of female and male participants (female = 5, male = 2). Three out of the seven participants had also been part of the exploratory research at the beginning of this thesis (see Chapter 3 'Empirical Research'), while the remaining four participants had not been previously exposed to the project. Five out of seven participants were of Dutch nationality and living in the Netherlands at the time of this study. One participant was of American nationality and living in the US, and one participant was living on Curaçao at the time of this study. Even though the number of participants for this study was limited, the representation of international perspectives is considered desirable for this study, as it might give initial insights into foreign perspectives that can lead to a broader perspective on the desirability of fully 3D printed children's footwear. All participants were directly contacted through WhatsApp and/or Instagram. Further correspondance was done through email, in addition to the previously stated communication channels. All interviews were conducted through Zoom. No compensation was provided to any of the participants.

Results

The audio recordings and written notes that resulted from the conducted interviews were analyzed and common themes were identified. In this section, the results of this study are presented, following the general topics that were also described in the interview guide that was designed for this study.

Aesthetic Value & Style Fit

Based on the images that were presented, participants were able to give a clear description of the perceived aesthetic value and style fit of the collection of shoes. For most parents, the product reminded them of water shoes, gardening footwear, rubber boots, production tooling and/or Crocs, based on the material that was used and uniformity of color.

"I actually thought they were some kind of water shoes, but in different models ... I think due to the design and also the material." - p1

"First thing that comes to mind is Crocs, right?" - p2

"Is this really the appearance of the shoe, or is this just the fitting last?" - p3

The rain boot style was most commonly picked by parents as the preferred style, especially for wet conditions. The preference for other styles varied based on the child's gender, clothing style and activities. The barefoot style was generally considered least attractive, based on visual appearance, due to its wide and round toebox.

"I think the water boots [are useful for daily use], because she also has rain boots" - p1

Various parents have pointed out the uniformity and minimalistic style of the products. A lack of detail and desire for multi-color options was brought up, as well as a more traditional style.

"Or even two-tone with the sole being one color and the other texture being another color ... I would choose one that can go with multiple things, so like black and red, or grey and blue" - p2

"My own taste is a bit more classic, so I wouldn't be so inclined to choose that very shaped shoe ... That's just a bit too modern" - p3

The material of the shoes was in most cases correctly identified as rubber or plastic, and brought up the question whether the product was made from recyclable material. One participant was unsure if the material in the open wall parts was rubber or fabric.

"Is this fabric? Is this like a breathable fabric? It looks like it is rubber ... Does the texture feel like fabric or is it like a rubbery mesh?" - p2

Participants initially did not identify the product as being 3D printed, until further explanation about the product was provided. One participant noted a worry about the potential of surface imperfections or 'printing artifacts'.

If you zoom in, you see those 3D artifacts on the edges, which makes me think 'It's really 3D printed, will that be nice?'." - p4

Two parents with both a twelve year old son noted concerns or an inability to judge to what extent their child would like the visual appearance of the product.

"I think [my sons] would be very much interested in the sneaker style. I don't have girls. I think ballerina's would align with girls ... I am really curious what [my son] would think, if he also thinks what I think ... I am not totally sure what his choice would be" - p7

"My child is twelve, so he has been thinking about very different types of shoes for a few years. They must be large Nikes or Adidas with very strange soles" - p4

Overall, the styles and colors that were presented covered a good range options and were considered suitable for a variety of occasions.

"The white shoes, kids kind of mess up white pretty quick, but the shape and design of the shoe, it looks really nice. You could wear it with slacks and it wouldn't look like you're just wearing rubber shoes." - p2

"If I was purely based on color, I would think it would look nice anyway. I think they are colors that are also often used in children's clothes. And in terms of style, I think.. We use a lot of wool clothing ... I think it fits ... I really like the design and the colors too." - p6

Additionally, the colors were generally considered desirable for children.

"This certainly suits my child's taste, because she really likes Crocs and these kinds of colors" - p3

Customization & Gift Giving

The ability to customize a first pair of children's shoes was generally considered highly desirable by participants, as it could lead to greater sentimental value.

"So fun! ... It is really nice to remember which child of what age started walking at what moment ... I should have written this down, I thought I would remember it" - p5

"Certainly! This is really fun! That doesn't exist yet, something like that. Also, [currently]you have shoes, but you don't put them on a baby yet, because they are too hard, and you have those slippers that often come off. So this seems ideal to me." - p3

Exception was one parent who did not consider the style and material of the shoes presented suitable for a first pair of shoes. This participant preferred name brand or hand made products more suitable.

"I wouldn't consider this a product for the first pair of shoes. Those are often shoes that are very special ... I see these much more as functional shoes ... I wouldn't give someone's child Crocs as their first shoes ... What you tend to see are very small brand shoes ... or that someone made by hand, that would be really special." - p4

Most parents did consider such a pair of personalized shoes a great gift to give or receive. The idea to gift this product was brought up by multiple parents, before this option was mentioned by the corresponding researcher.

"And also perhaps as a gift, that you can give it to someone. I don't know if I would do it for my daughter myself, but if someone gave this to me I would like it." - p6

It was mentioned that for the product to be given as a gift, parents would need to trust in the product's performance and usability. Additionally, knowing which size to buy as a gift was mentioned as a potential barrier.

"If we have good experience with it then I would do it... That it is at least something that is not just worn once and then like 'oh it doesn't really work' and it ends up in a corner somewhere" - p6

"It is also very nice to give as a gift, but you must know the baby's size. That is always difficult." - p3

A surprising finding was that parents also considered the aesthetic customization with name of the child especially desirable, as it could prevent shoes from getting lost.

"Personalizing works in a daycare setting though. Personalizing works for little kids, because their shoes are labeled ... That would be a big selling point ... Because shoes get lost at daycare" - p2

"For very practical reasons, for example when [my daughter] goes to daycare, if you take personal things with you that are really valuable, you put your name on it or put a label on it or something, because things often get lost " - p6

In this case, the placement and general visibility of the name should be potentially reconsidered.

"But you don't want everyone else to see their name, so if you did personalize it, it probably would not be in that location" - p2

Protection

The perceived ability of the product to protect the child's foot varied. Many parents were concerned about the product's ability to keep their child's feet warm during colder seasons.

"It looks like plastic, so I doubt if [my daughter], in the winter, would have warm feet in them." - p1

Parents did consider the rain boots style suitable for wet conditions during fall and spring season, while other styles were generally considered more suitable for dry conditions, beach settings, summer season and vacation.

"I think it very much depends on the use. If it rains and the weather is dirty, take the waterproof one. And in the summer you can choose the breathable shoe." - p6

Support

With regards to the perceived support of the presented product, participants wondered if the footbed would be able to provide sufficient support for their child's feet, due to the novelty of the product and manufacturing process. One participant, however, noted that one of the styles was perceived as more supportive of sportsy activities than other foam or rubber footwear like Crocs.

"When I think of 3D printed shoes, I would think: the potential of fit 'Wow, that's interesting', and at the same time I think: 'That footbed, is it going to be strong enough, firm enough and provide good support in the right places?'." - p4

"Maybe not professional, but [the blue shoe] looks like it's got a little bit of a springy heel, so they can actually run. Because if you were to run in Crocs, it's not that great" - p2

For one participant, the flexibility of the product stood out, as less support might be more beneficial for natural foot development.

"It's great that this material is so flexible. I think it's wonderful for a child that you can just feel your own feet well... I think you can make your feet sturdy by not having the sole too stiff and not giving it too much support." - p3

Comfort

The perceived comfort of the product was generally considered high, as participants were quick to recall prior experience with Crocs or water shoes.

"You also have closed Crocs for the summer, those are also plastic shoes. I believe that's comfortable, so that would not cause any doubt when I would see [these shoes]." - p1

"It looks very comfortable to me, because I really like water shoes myself" - p3

One participant was wondering if the shoes would also be comfortable without wearing socks inside.

"Would they chave in there? If their feet are just rubbing around in there, giving them blisters potentially, or is it recommended to be worn with a thin sock? ... People would probably get them because they don't have to wear socks. It's something quick for the kids to pull on and probably easy to clean" - p2

Breathability

The perceived breathability varied strongly among participants. Some considered the product to be highly breathable, while others were concerned about a potential lack of breathability, due to the material and design of the product.

"It looks like a highly breathable shoe to me, so really for the summer or warm spring days." - p1

"I am wondering what the breathability is. Is this rubber? Are there any ventilation holes?" - p2

"I just have some doubts about the material I think. Whether plastic is nice to wear ... The humidity or stickiness ... Then it must be airy enough, I think. I'm curious if that is possible." - p3

Durability

The product durability was generally considered very high, while expectations of product lifespan would also depend on how the product is marketed.

"I think they will survive a nuclear attack ... Because it is plastic" - p4

"It looks like it can take a beating, because it is also one whole, so it cannot fall apart" - p6

Ease of Use

The expected ease of use for the presented products varied amongst participants. While some considered the slip-on mechanism easy to use, others were concerned about the child's ability put these shoes on by themselves, most as a result of the unkown stretch of the collar area and lack of pull tabs. Ease of use expectations also varied among the different styles and ages.

"I think that such slip-on is more difficult [than velcro] for young ones.. Actually, I am sure that it's more difficult. They cannot do that themselves, so you would have to help them every time." - p1

"I think she can put on all of these easily, so that is very handy ... I don't know if the purple [shoe] is easy. That one might need a pulltab that the child can pull in the back" - p3

Participants had varying ideas about the ability of the product to stay on the foot of the user during activities.

"It really has to stick to your foot, so to speak, when you play football, run, play, does it stick to your foot? ... With normal shoes, you work a little and then [the feet] expand, then you can tighten the laces a bit" - p4

"She has those slippers that she takes off all the time, so she always ends up barefoot. And when I look at [the shoes] like this, it looks like it fits nicely around the foot... Seeing the material, I would think that it retains its shape, so there is probably a greater chance that it will stay [on her feet]." - p6

"Half sizes might be necessary, because this kind of shoe, if it's a little too big, their heel will keep popping out. So that creates kind of the half size situation." - p2

The ease of maintenance was considered very high, due to the product being machine washable.

"I can put them into the washing machine?! Wow! And nothing happens to the material? That is a big plus!" - p5

Health

When asked about the expected health impact of the product that was shown, participants were not able to come to a conclusion yet, as more information and proof of concept was needed. A lack of previous users and the idea that the concept is still experimental would prevent some users from considering the product.

"When I think of 3D printed shoes, I would think: the potential of fit 'Wow, that's interesting', and at the same time I think: 'That footbed, is it going to be strong enough, firm enough and provide good support in the right places?' ... 'Am I ruining my children's feet with it?' It would be an experiment, but at the same time there is value in it" - p4

Special Needs

Participants with personal experience when it comes to children with special orthopedic footwear needs considered highly personalized 3D printed footwear as a big step forward, compared to available solutions.

"I also see a lot of possibilities for children who may not have normal feet and who could now make perfect shoes, instead of those ergonomic, leather, very scary things." - p7

Discussion

This study has provided initial insights into the perspective of parents as decision-makers on fully 3D printed children's footwear. The presentation of the collection of printed shoes evoked a large variety of reactions and associations among different participants, and significant differences were found between the desirability of the different styles that were developed for this test. Due to the style's familiarity and its resemblance to existing products, most parents were initially drawn to the rain boot (see figure 23), having no concerns about the aesthetic or functional value of the product. The ballerina (see figure 27) also benefited from the same familiarity, and was met with positive feedback from various participants. Other styles were harder to assess, and, while multiple parents considered the aesthetic value of these styles desirable, it was also found that parents find it hard to imagine how their child would react to fully 3D printed footwear. While novel, the aesthetic of the product was generally considered acceptable and appropriate for children. Further interest and product adoption would largely depend on the child's perception of the product. Therefore, future research should focus on exposing the product to children of various ages to determine the desirability of the product to children. Furthermore, reactions from particants suggest that familiarity with the style is important for parents as it allows them to mentally categorize the product more easily, and imagine possible use cases. The need for categorization and presentation of imagined use cases was further highlighted by the request of multiple parents to be provided with pictures of each style in a real world scenario and a clear description of the product features.

This study suggests that the barefoot style (see figure 26) is considered most appropriate for very young children due to its flexibility, but mostly undesirable for children of older ages due to the shape of the front of the shoe, and an overall aesthetic that was more akin to a water shoe than footwear meant for daily use. Some participants extended the comparison to water shoes to all of the footwear styles, with the exception of the rain boot. Crocs were also commonly associated with the presented 3D printed footwear. While the perceived product comfort benefited of these associations with existing foam and rubber footwear, other perceived product characteristics were negatively affected by such comparisons. The study suggests that parents are generally unsure about the product's ability to provide sufficient support and breathability to support everyday wear by their child. While the open printing texture might be enough to convince some parents of the product's ability to wick moisture, others remain concerned about the ability of plastic footwear to be breathable without the addition of larger holes. Other than breathability, a major concern for almost every participant in this study was perceived lack of ability of fully 3D printed footwear to be used in cold weather conditions. While this was of no concern to one participant, living in a geographical location with warm weather year-round, other participants quickly determined that the product would not be usable during the winter. This is an important challenge to address as the proposed new product-service system aims to provide the user with footwear throughout the year.

This study also found that, despite variations in printing texture and the experimentation with different shapes, the presented products were generally considered minimalistic. It was suggested that future product development should focus on the addition of more design details and multi-color options. Two parents, however, expressed their excitement about the aesthetic quality of fully 3D printed footwear in combination with the promise of a personalized fit, compared to existing orthopedic footwear. This raises the question if fully 3D printed children's footwear could best be focused initially on children with special footwear needs, or if such associations should be avoided, as it might negatively affect associations around 3D printed footwear.

Surprisingly, the expected ease of use of the product varied strongly amongst participants. While some participants considered the slip-on mechanism very easy to use, compared to shoe laces, other parents were initially concerned about their child's ability to use the product on their own. This was related to concerns around the amount of stretch in the collar area, where the foot enters the shoe. Upon further demonstration of the product and stretch

around the collar, however, these participant were less concerned about this. Further product development should include thorough testing of the ease of use 3D printed footwear, and consider possible design modification, like the addition of pull tabs and the amount stretch that is provided in the collar area of the shoe. Similarly, user testing is needed to determine the product's ability to stay on the user's feet during various activities. As one parent noted, the slip-on mechanism would likely require the sizing to be within half a size to the foot at any point in time. To prevent very fast replacement of the product, future product development should consider the addition of removable insoles, linings or socks, the stretch of the upper, and other solutions that could facilitate some of the child's foot growth and ensure a good fit over time.

With regard to the desirability of aesthetic customization of a child's first pair of shoes (see figure 28), it can be concluded that such a feature is highly desirable to most parents and would be capable of increasing the emotional value attached to a first pair of shoes. Furthermore, such a customized product would be considered a desirable gift to give and receive. However, the ability of the parent to provide the correct size, and sufficient trust in the product's usefulness are important thresholds for parents to engage in such gifting behavior. A surprising finding of this study is the extended use of such aesthetic customization and desirability of such a feature beyond the first pair of shoes. The addition of a name to a pair of children's shoes was considered of high practical value to multiple parents in a daycare scenario, where shoes were often lost and mixed with those of other children. Further testing and product development should consider the availability of such customization options beyond the first pair of shoes. For such applications, the placement and general visibility of personal information should also be reconsidered, as it becomes of practical, rather than sentimental value.

Key Takeaways & Design Considerations

- Variation of open and closed walls allows for the creation of children's shoes with more or less breathability and water resistance. However, there are significant challenges with the creation of one product that is both breathable and water proof.
- 3D printing with TPU brings unique challenges, resulting from the material's tendency to stretch and rapidly absorb moisture. Reduction of print failure rate requires careful control of the print environment and print settings.
- Parents frequently associate fully 3D printed children's footwear with water shoes and Crocs. This can positively affect the product's perceived comfort, but negatively affect its perceived ability to provide sufficient support.
- Showing the product in a real world and use context is essential to help parents imagine how they could use and style 3D printed footwear.
- While novel, the aesthetic of the product was generally considered acceptable and appropriate for children, and daily life.
- Fully 3D printed children's footwear is not considered suitable for cold weather conditions, due to a perceived inability of the product to provide warmth. This is an important challenge for a system that aims to be used year-round and grow with the user at every step.
- Perceived ease-of-use varied significantly among parents. User testing is needed to confirm or optimize the design of the product to facilitate independent product use by children.
- Aesthetic customization of the first pair of children's shoes was found to be highly desirable by parents. Additionally, this was considered desirable for gifting purposes. However, trust in the product's usefulness, and the ability to gift the correct size are essential for parents to engage in the gifting of this product.
- Possible practical benefits of aesthetic personalization of children's footwear and the visibility of personal information on the shoe should be considered for future product development. The benefits should be weighed against the the end-of-life consequences, as this would lead to further reduced possibilities for product reuse.
- Further product development should consider the addition of removable insoles, liners or socks, stretch of the upper, and other solutions that could allow the shoes to facilitate foot growth and prevent rapid product replacement.

07

Experience & Service Design

This chapter describes the process of creating a concept design for a retail experience and mobile service as part of a new product-service system for 3D printed children's footwear. First, it provides an overview of relevant retail developments and trends that shape the future retail context. Second, the desired future interactions are explored through analogies and AI-driven exploration. The information in these sections is combined with the physical product design and the insights from previous chapters for the design of a concept retail and service experience. Through testing with end-users, this chapter seeks to test the concept and provide insights for future experience and service development.

7.1 Future Retail Context

Phygital & Omni-Channel
Role of The Retail Assistant
Social Commerce
Instant Delivery
Shared & Temporary Retail
Personalized Experiences

7.2 Future Interactions

Ace & Tate: Analogy for Design of A Shopping Experience
Efteling: Analogy for Design of A Shopping Experience
Exploration of Future Interactions with Midjourney

7.3 World's Smallest Biggest Shoe Store

Meet Luca!
In-Store Experience
Mobile-User Experience

7.4 User Testing

Research Method
Results
Discussion

Key Takeaways & Design Considerations

7.1 Future Retail Context

This section summarizes a selection of retail trends and developments that are relevant for this project. The resulting future retail context provides important guidelines for the creation of a future retail and service experience as part of the proposed product-service system.

As stated in chapter 6, the creation of a circular product-service system for children's footwear in this thesis involved the development of three core parts: a physical product, a retail experience and additional services. These parts were developed simultaneously and co-evolved throughout the project. While chapter 6 detailed the design of the physical product, this chapter describes the process and results of the design of a new retail and service experience for users of the system. In order to understand the future retail landscape that the new shopping experience will be placed in, current and future retail trends and developments were analyzed. What follows is a brief overview of the most relevant factors that guide the design of the new shopping experience as part of the new product-service system for 3D printed children's footwear.

Phygital & Omnichannel

As we delve into the future of retail, the move to phygital, a combination of physical and digital retail, stands out (Das, et al., 2023). As traffic in most physical points of retail is almost certainly going to decrease permanently, with a mass shift to e-commerce, being able to maximize the value of each trip is going to be incredibly important (Adhi et al., 2021). On the other hand, US retailers announced approximately twice as many store openings as store closings in 2021, with some of them being opened by digitally native brands that used to operate purely online (Burns & Harris, 2022).The collision of physical and digital retail could provide a completely seamless and connected customer experience, by building a consistent customer journey across every physical and digital touchpoint. By providing an experience that includes both physical and digital elements from which customers can choose, customers are able to tailor their experience to meet their preferences, as they decide how they want to interact with a brand, how they want to buy and receive products, and which services they want to take advantage of in-store (Hughes, 2022). Whereas a few years ago, the omnichannel customers were expected to be much more valuable than single-channel shoppers, the past couple of years have given time and data to confirm this, as omnichannel customers were found to shop 1,7 times more than single-channel customers, while also spending more.

"The in-store customer, going forward, will be someone who is hitting all the different channels and touchpoints that a brand or retailer has. That means consistency and connectivity between all those channels will be really important." (Burns & Harris, 2022)

Whereas traditional retail stores often provide direct access to products, based on a certain amount of stock, a move towards phygital retail experiences could result in a focus on flagship stores that are primarily used for "showrooming" (Adhi et al., 2021). A store from GU Style Studio in Harajuku, Japan provides a example of the combination of physical and digital elements to create new types of experiences at physical points of retail (see figure 32). Through the adoption of virtual and augmented reality technology, companies like Sephora, Alibaba and Lamoda are experimenting with virtual try-ons, with fashion retailer Lamoda's virtual shoe shop being accessed by around 150,000 mobile users a month following its successful launch in 2019, allowing users to see themselves wearing any one of their 400 boots and shoes by simply pointing their smartphone camera at their feet (Das et al., 2023; Natanson, 2021). Additionally, Snap launched its new SaaS business unit last year called 'ARES', which will help retailers to make use of AR and AI tools, and enable digital and in-store virtual try-on experiences that are based on the company's experience with virtual lenses and filters (Vasani, 2023). Companies like Nike are increasingly using the digital landscape to drive hype around new products and create

Figure 32: GU Style Studio store blending physical and digital shopping (Maki & Du, 2018; Du & Maki, 2018)

communities around special releases and sports communities. In order to deepen customer relationships, brands are shifting towards measuring their customer's "share of life", over traditional metrics like "share of walllet". Rather than selling product, the activities of forward-thinking retailers are focused on creating an ecosysten that allows them to become part of their customers' life, and give them more reasons to spend more of their time and money with the company, allowing for generation and monetization of customer data. However, this shift also requires companies to rethink their positioning along the value chain:

"The opportunities are vast and varied, so it's essential to make smart decisions about where in the value chain you'll play and where you'll partner." (Das et al., 2023)

Role of The Retail Assistant

With a change in the function and expectations of a physical retail experience, there is also a change happening in the role of the retail assistant. With a focus on speed, the introduction of self-checkout, and AI powered tools like ChatGPT becoming the primary mode of customer service for digital natives, personal interaction is increasingly taken out of the equation. On the other hand, the introduction of technology also provides retail assistants with more time and the opportunities to tackle complex issues, making the customer journey better than ever (Carrasquilla, 2023; Burns & Harris, 2022). Rather than removing store employees entirely, the store of tomorrow requires associates that are digitally trained, understand new customer dynamics and have objectives that are aligned with the omnichannel customer experience they are part of:

"..shoppers want to be able to walk in and out of a store and not interact with a salesperson if they don't need help. But zero desire for assistance is not about having a store with no employees; it's about redeploying store employees to provide the services that customers actually want" (Burns & Harris, 2022)

Social Commerce

The trend of brand collaborations with social influencers to drive increased sales is continuing to explore new media. In both China and the US, this is visible in the sales of goods and services through social commerce channels like Instagram, WeChat and Tiktok. The power of influencers and community leaders is harnessed by brands through collaboration with "key opinion leaders" (KOL), who have gained massive following by becoming subject matter experts in their respective categories, and "key opinion consumers" (KOC), microinfluencers driving social commerce through organic, word-of-mouth recommendations to their personal networks. Through direct brand collaborations or early access to new products, brands engage with these people for promotion and input on product design (Becdach, 2022). With these efforts brands hope to tap into the growing spending power of millennials and Gen-Z:
"Together, millennials and Gen-Z, who already derive much of their influences from social media, online content and celebrities, are projected to account for over half of the global population by 2030. As these cohorts age, their spending power will grow significantly, parallel to their dominance." (Lammertink, 2022)

Additionally, social commerce meets people in the places they like to spend their time, and caters to people's need to feel inspired, informed and confident in their purchases, in a world that is dominated by ads. The focus is increasingly shifting towards building authentic connections between consumers and the brands they interact with (Lammertink, 2022). The impact of creators and influencers in today's economy is further demonstrated by the amount of new successful brands they are initiating nationally and internationally. With the creator economy now believed to be worth over $100 billion, influencers are increasingly successful at leveraging their existing follower base to start new ventures in a variety of industries, including fashion, food and cosmetics (Robehmed, 2019; Kelso, 2022).

Instant Delivery

With the shift from physical retail to primarily e-commerce of certain goods also comes a rise in the amount delivery people, vans and trucks rolling into cities to make deliveries (Hower, 2019). Expectations around delivery times have significantly advanced, as five years ago, people did not expect an online order to arrive in less than a week, while people currently track their package going down the street (Burns & Harris). Expected delivery times are quickly decreasing, as 24 hour delivery is becoming the standard in many places around the world, and 12-hour delivery being promised, pan-China, in five years. In fact, as new aircraft hubs are opening to enable a very fast exchange of goods, the majority of products for most customers in most Chinese cities are expected to be possible within six to twelve hours after an order is placed, much sooner than 2030 (Huang, 2019). In order to meet delivery time expectations, micro-fulfillment centers are being placed in densely populated urban locations that are closer to the consumer. Such centers can be created in the form of small-scale warehouse facilities, or they can be installed inside stores, generating new valuable strategic opportunites for retailers (Ladd, 2022). With the recent rise of ultra-fast fashion brands like Shein, developing and delivering new items every day, and startups like Need It For Tonight promising 90-minute delivery times, it raises the question how fast can retail get, and if this is desirable for consumers and the environment (Salah, 2023). Furthermore, it raises the question "What is worth the wait?":

"That's the flip side for retailers: figuring out what is worth the wait and making those experiences and products really treasured, because there's a magic to that in a world where you've got all of this instant noise." (Burns & Harris, 2022)

Shared and Temporary Retail

The potential of shared and temporary retail spaces for brand activation and improved customer experiences has become increasingly visible, as it allows companies to purchase a small space in a region that makes sense for them, for a limited amount of time. This comes with the ability to play around with those variables and learn how much investment different geographical locations can sustain in terms of moving products and overall ROI (Narkulla, 2019). Additionally, "shared retail" or "co-retailing" can provide additional benefits for customers when brands choose retail partners that offer target customers complementary products or services, rather than alternatives (Walls, 2022). Concrete examples of such spaces can be found locally with spaces that combine a women's wear and a men's wear brand under the same roof, or a camera and drone brand sharing a space and possibly even their sales associates due to their overlapping areas of expertise. The ability to offer complementary products and services allows retailers to create new types of unique and memorable experiences that customers want to return to, further blurring the line between a shopping and a lifestyle destination (Do, 2022; Marhamat, 2022).

Personalized Experiences

With the increase in digitally connected and data driven retail experiences, also comes an increase in the ability to personalize and tailor these experiences to fit the individual customer. While such experiences are becoming the norm rather than the exception in the e-commerce space, personalization has remained more rare in physical retail. However, with a shift to phygital, in-store experiences can possibly become more personalized too:

"There are companies out there that are personalizing the sounds you hear in the store and the scents that you smell. They're personalizing what the associates know about you to help you find the right product more quickly. You're going to see digital mannequins that quickly change what they're wearing based on who you are and what you might be holding in your hand." (Adhi et al., 2021).

Companies are required to engage with AI and cross-functional teams to make such highly personalized experiences possible (Das et al., 2023).

7.2 Future Interactions

In order to inspire and generate new ideas for the shopping experience that is proposed, analogies were used to describe the customer journey and future interactions. Furthermore, future interactions were explored visually through the used of AI image generators.

Ace & Tate: Analogy for Design of A Shopping Experience

Health and Aesthetics

As Mark de Lange, Founder of Ace & Tate, has noted: “The reason for starting the company is that when you wear glasses, it is more akin to going to the dentist than buying a nice product for yourself, although it sits on your face and it is an extension of who you are” (Techleap, 2021). The parallels with a dentist visit might stem from the health aspect of a pair of glasses. Parallels can be found between the functions of glasses and footwear, as both products are assessed on their identity, social and physical fit. These products both have an enabling or supporting function, as glasses are the medium between the user’s eyes and the outside world, allowing the user to see, while footwear is the medium between the user’s feet and the outside world, allowing users to move around. However, as these products are highly visible while being used, and worn directly on the body, the aesthetic quality and symbolism also plays an important role and, therefore, strongly drives the customer’s choice.

No Compromise

The current selection process for children’s footwear often requires parent and child to make a compromise between the aesthetics and the physical fit of the shoes, as they are directly tied to each other. The goal of this project is to design a system that removes such barriers and the need to compromise. Rather than traditional footwear shopping, a future system for children’s footwear should feel like choosing a pair of glasses at Ace & Tate. The customer journey at Ace & Tate starts with a quick eye test to determine the correct strength of your lenses, under the guidance of a trained professional (see figure 34). After your measurements have been collected, you are allowed to freely roam around the store and easily try out and compare any frame you want, instantly. The collection of different styles and colors is carefully designed to match style and fashion trends and connect with the target user, while also delivering a product that can be considered high-quality. After you have found the frame you like most, you can let the store assistant know your choice and an order is created based on your frame of choice and eye measurements. Finally, the personalized product of choice is delivered at your house a couple of days later. The ability of this system to provide users with a very low friction experience and highly personalized and stylish product is something that should inspire the design of a new system for children’s footwear. Such a system would remove the need to prioritize aesthetics or physical fit and foot health, and provide a system that is far more inclusive.

Direct to Consumer

By following a direct-to-consumer model and the opening of brand stores in urban areas with a blend of cultural, creative and commercial appeal (see figure 33), Ace & Tate is able to build a specific customer experience and close customer relationship. This connection and direct interaction with users provides valuable data and feedback, and allows the brand to better understand the specific and changing customer needs, which is crucial for product development, marketing strategies and overall business development. The ability to directly control the customer experience also allows the brand to create a strong brand identity and ensure a consistent product and service experience. As glasses are replaced and the user’s lens requirements change over time, staying close to the customer, building a consistent and fulfilling customer relationship, and increasing customer loyalty allows the brand to grow with its users.

Figure 33: Ace & Tate store in London’s Soho (Levy, 2018)

Figure 34: Child in eyesight measuring process (Draulans, 2023)

Figure 35: Parents with children in the Efteling (Efteling, n.d.)

Efteling: Analogy for Design of A Shopping Experience

Efteling is a magical place in the Netherlands. A place where parent and child can roam, play and wonder together (see figure 35). A place where everyone is a child. The shopping experience for the proposed product-service system takes inspiration from Efteling's capability to create a magical environment that encourages parent and child to explore together. The proposed product-service system for children's footwear seeks ways to involve the child in the style selection process, in order to facilitate the development of their own taste and style and allow them to learn with and from their parents. Therefore, the shopping experience of this new system should be designed to engage both parent and child in the shopping experience. The ability of Efteling to spark people's imagination also provides inspiration for the use of interactive storytelling to engage the users in the manufacturing process of the product they are buying and create a more educational experience.

Exploration of Future Interactions with Midjourney

In addition to analogies, an AI image generator was used to visualize and analyze the desired interaction of parent, child and the shopping experience (see figure 36 to 38). A variety of text prompts was used in Midjourney to generate an initial set of images and large amount of variations. Prompts included the terms 'parent and child', 'future world scene', '3d printing' and 'biometric data'. Most of this exploration relies on experimentation, chance and intuition. The different types of interactions and positioning of the parent in relation to the child(ren) (e.g. facing each other, standing next to each other or standing behind or in front of one another) served as starting point for the design of the shopping experience that is later described. Additionally, the produced visuals provided an early way to rapidly capture the desired feeling of the shopping experience and created a large amount of suprising and potentially overlooked interaction, effectively using AI as a tool for early design exploration.

Figure 36: Two children and a father at a futuristic, interactive shopping station. The smallest child is directly facing what looks like an interactive screen, while his father is holding a device, possibly controlling the environment and things that are displayed on the screen that the smaller child is facing. All three characters are standing inside the shopping station and are engaged in different ways. The father stands behind his children, being more in the background of the experience, while the child is in front, and directly engaged with the big interface.

Figure 37: A daugther and her father are both standing on what looks like a foot scanning platform. This variation stands out from the others, as parent and child are directly facing each other. The viewer might wonder if both the parent's and the child's feet are being scanned simultaneously, creating a shared experience.

Figure 38: In this image, parent and child are seen looking over the edge and into the distance. The parent is holding the child's hand, and the child is holding the parent's. It might suggest the parent guiding the child as it steps into a new journey. The child gazes into the horizon and wonders.

7.3 World's Smallest Biggest Shoe Store

This section details the design of an in-store and mobile retail and service experience, as part of the proposed PSS for children's footwear. This includes the design of the user interface and a physical setup needed to realize the envisioned future interactions in the described future context.

Introduction

Exploratory customer research detailed in chapter 3 of this report pointed out a general shift by parents toward online consumption of children's footwear, aligning itself with broader retail trends. More convenience and more choice are key drivers for this reduction in store visits, especially when children are involved. Measuring a child's feet, going through the options together in-store, waiting for the store assistant to find the correct size, and trying on multiple pairs to find a pair that sufficiently meets physical fit and aesthetic criteria for both parent and child, it is encouraging many parents to search for online solutions. However, as became clear through the conversations with parents that were part of this project, this shift to online shopping has also resulted in a significantly reduced engagement of children in the footwear selection process. This includes both physical fit and style. The design of online stores for children's footwear reflects this lack of involvement of the child. Monotonous product pages with white or grey backgrounds and little differentiation from any other online store provide an experience that seems highly catered to the interaction and lack of the child's involvement that exists today. This is in stark contrast to the design of physical stores for children's footwear, which are often designed to resemble playgrounds, tapping into the child's desire to use retail environments as places of play, and promoting movement and product trial. The design of a new omni-channel customer experience for children's footwear should inspire and facilitate fun and easy and co-consumption of footwear, involving the parent and having the child as an integral part of this process. This allows children to learn and develop their own style, increase the chances of finding an optimal physical fit, while also effectively reducing the amount of returned and unworn pairs that result from a lack of involvement of a child in the initial selection phase. The design process has led to an omni-channel customer experience that consists of both a physical retail experience and an online part, working together to provide users with an experience that helps them to find shoes with an optimal fit.

Meet Luca!

At the heart of the customer experience for users of the new product-service system for children's footwear is Luca. Luca is parents' new personal assistant for their child's footwear and healthy foot development. Whether online or offline, Luca assists the child's footwear journey from their first steps, helping them to explore and develop their own style, and setting them up for lifelong foot health. Luca is designed to be a friendly face that both parent and child can turn to for help with their feet and footwear at any moment, in-store and online. An important reason for the creation of a friendly character as the central point for user communications is the goal of turning the professional voice into a familiar one that provides consistent and friendly communication, while being able to communicate health related information. The importance of familiar voices in the footwear selection process was stressed previously, in exploratory research detailed in chapter 3 and literature, as many parents are likely to seriously consider advice with regards to foot health and footwear from people they know, even prefering these voices over professional ones, such as a podiatrist, fysiotherapist or store assistant (Hodgson et al., 2021). Recent breakthroughs and mass adoption of artificial intelligence have paved the way for a next era of highly capable personal assistants and chatbots. This creates opportunities to create a digital, automated point of communication with users, that also has access and can communicate highly specific and tailored information for a personalized and efficient interaction. With Luca, the goal is to create a digital but familiar face that effectively and efficiently communicates with both parent and child. An initial character design of Luca is presented in figure 39. The resemblence to a

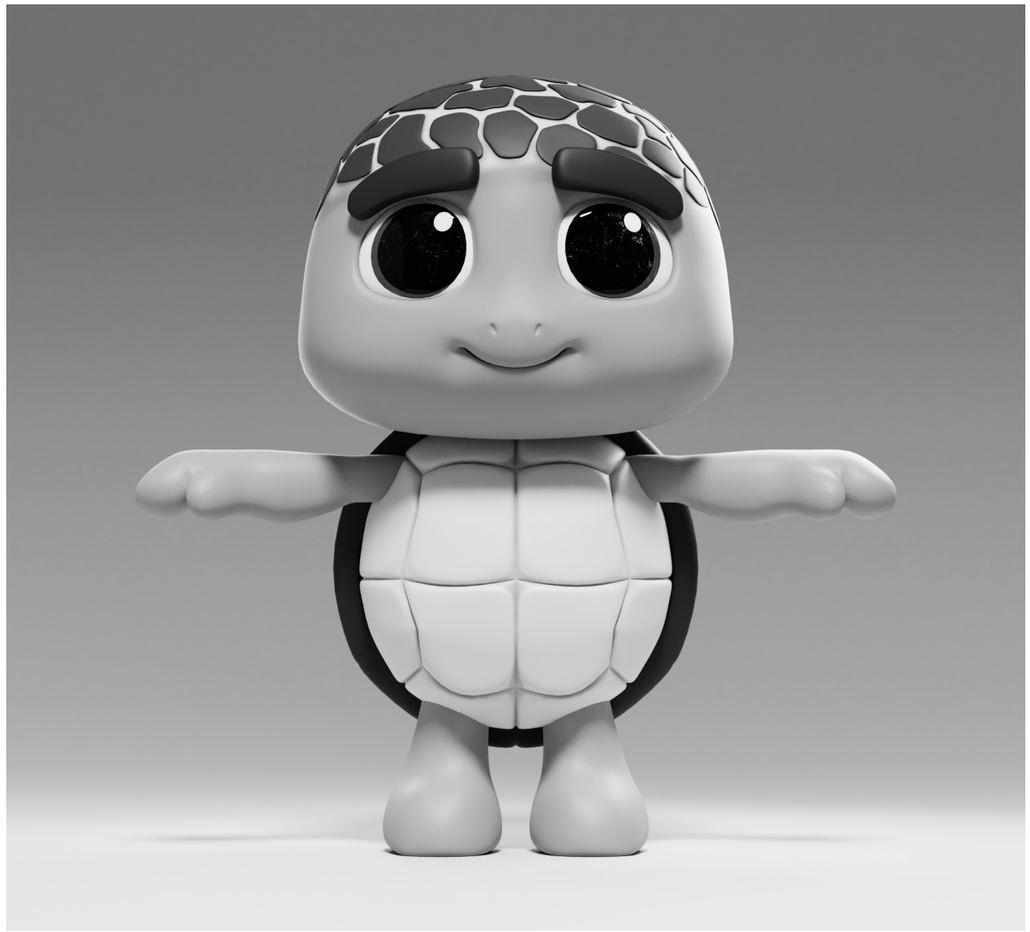


Figure 39: 3D render of Luca character

turtle was driven by the analogy to the desired future state of footwear that this creature carries. Currently children's feet are molded to the shape of their shoes through consistent and long-term wear. Rather than growing with the malluable and developing feet of the user, the effect of shoes is currently more akin to that of a flowerpot that shapes the roots and determines the growth of the plant. In contrast, the shell of a turtle is a stiff structure that provides the soft body with the protection it needs for the environment it functions in, but it also grows along with the soft body. The new product-service system for children's footwear aims to fulfill a similar function, protecting the child's feet, while growing with the user, rather than the user's feet growing to the shape of the product. In addition to physical growth, the growing child also experiences a lot of psychological development between the age of their first steps and the time they reach the age of twelve. As first-time parents are continuously learning and growing into their new role with new knowledge and experiences, they too grow along with the child. Therefore, it is important that Luca not only provides a great user experience for both parent and child, but that it is able to grow with its users and provide a personalized experience throughout the child's footwear and foot development journey. This capability to grow with its users psychologically is likely to be achieved through the application of currently available and evolving artificial intelligence, and the data that is generated, collected and processed through continuous interaction between users and the system.

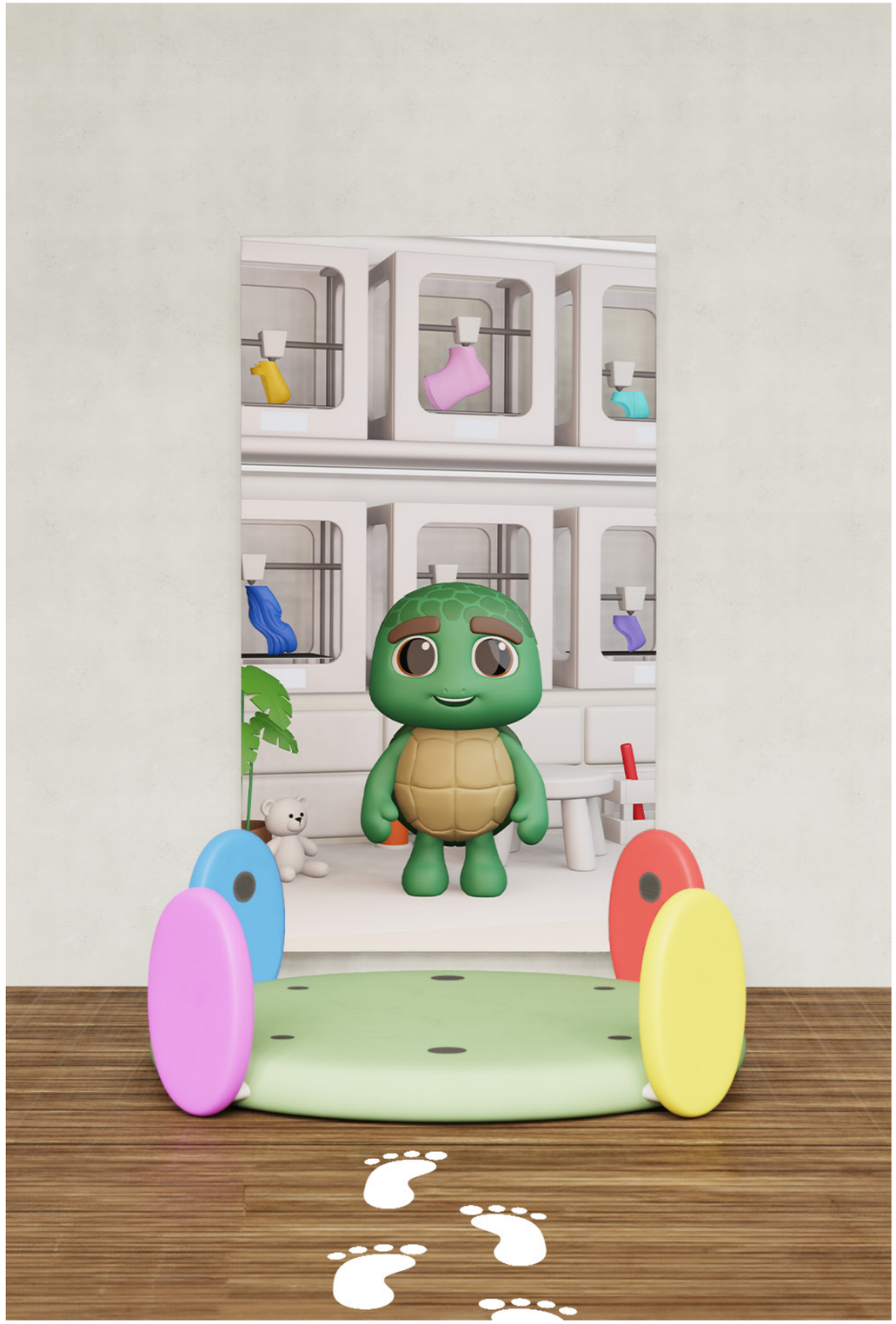


Figure 40: 3D concept visualization of LUCA shopping station

In-Store Experience

The omni-channel customer experience is built around a store concept that puts the child at the center of the experience and makes it convenient and desirable for parents to engage in the activity. Figure 40 shows an impression of a possible store experience that takes the child through the steps that are required for ordering a new pair of shoes. The product that is offered through this system is entirely 3D printed, with a personalized fit. Therefore, it is of great importance that high quality measurements from the child's feet are collected, as this will serve as input for the creation of the shoe that is produced. The high quality static foot scanner from Volumental (see figure 14) was used as a base for the design of the scanning platform. From personal observations as a formal retail assistant in children's footwear, I had noticed that the shape and aesthetic of available foot scanning options has the risk to scare some children. Therefore, while the Volumental machine was used as a base for the sensor layout, the appearance of the machine was adjusted to become more approachable and more likely to attract young children. Additionally, small foot steps were added as a cue that guides potential users to the platform. As fit technology companies like Volumental and Safesize, as well as more research based and open-source alternatives, increasingly start to offer online solutions for foot scanning, the choice to create an in-store foot scanning experience might seem like it is adding unnecessary friction to buying children's footwear. However, current applications of mobile foot scanning have also demonstrated the limitations of such solutions. Zellerfeld has previously used a method of scanning the bottom of the foot with the camera of a mobile phone, to determine length and width dimensions. This, however, provides data that does not take into consideration the variance that happens when a foot is standing on the ground and bodyweight is directly applied to it. Other mobile foot scanning solutions use reference objects and ask the user to take multiple pictures of their own feet. This, however, complicates and significantly extends the measurement process, while still creating a lower resolution result than a dedicated machine with a variety of sensors under and above the foot. As parents have noted previously, getting a child to stand still for more than a few seconds can be a serious challenge. Finally, the use of a dedicated in-store setup for foot scanning can provide us with the data that is necessary to actually create 3D printed footwear with a highly personalized fit, even taking into account the user's bodyweight for adjustment of the cushioning density under foot. As products are created on-demand, when an order is placed by the user, it is extremely important that products fit right the first time, and ill-fitting products are prevented. As the main promise of the system is to produce footwear with a highly personalized fit, receiving ill-fitting footwear can be extra disappointing for users, and especially for children's footwear, where the user can quickly outgrow the product, receiving a 'misfit' is highly undesirable. Creating a store experience that effeciently and effectively captures the foot data of the child is therefore essential to the success of the proposed product-service system. The scanning procedure would allow for the creation of a product that follows the foot length, width and height dimensions, as well as sole density.

As children step onto the colorful scanning platform, they are greeted by Luca, who takes them through the steps that are necessary to complete the foot scan. Luca could ask the child to stand still, while he counts to three, or he could make it more fun if the child wants to do additional activities and movements. At the end of this process, the system is left with detailed data about the length, width and height measurement of the user's feet, as well as the pressure data that is collected through the sensors that are placed inside the baseplate. Together this renders a highly detailed image of the user's footwear needs, which increases the likelihood of a correct personalized fit. In addition to static foot data (feet are standing still in one place), which is most frequently collected by fit tech companies like Volumental and Safesize, future steps in foot scanning should include 4D foot analysis to provide a detailed image of the foot under movement, allowing for an even more personalized fit. Kwa (2021) has previously described the development of a low-cost 4D foot scanning device for podiatrists. Future application of such technology, in combination with the interactive experience that Luca provides could enable the collection of high quality fit and foot health data in a way that is fun for children and effortless for parents.

After completion of the foot scanning procedure, the style selection process begins. As the product is 3D printed only when an order is placed, this process differs from existing store experiences, as the product is not directly available on location. However, it is important that there is a style selection process that allows both parent and child to get an accurate impression of what the product will look like. As parents have also noted, it can be challenging to correctly assess a product online, as it is often shown on a white background, out of context, and not in interaction with a child. Especially for personalized footwear that is manufactured on-demand, it is important to minimize the chance of a return, as this product would likely be destroyed and the customer would have to wait a long time for a replacement product. Therefore, the in-store experience was designed to provide an accurate impression of the product that is selected in direct interaction with the user. The child is again at the center of this activity and directly engaged through the use of what can be described as a 'magical mirror'. As soon as the foot scanning process is completed, Luca lets users look in his mirror, showing the selected shoes projected onto the feet of the user. This process allows both parent and child to fully imagine what a certain pair of shoes will look like on the child's feet, and in combination with their clothes. This concept takes direct inspiration from the lenses and filters that have become increasingly popular on social media, allowing users to change or add to their appearance using the camera in their mobile phone. A first proof of concept is provided in this thesis through the creation of mobile virtual try-on prototypes through Lens Studio software from Snap AR (see figure 41). Integration with the highly detailed image that is captured through the foot scanning platform might further bring the product to life, as the shoe of choice is more accurately projected onto the user's feet and could realistically deform along with the user's movements. The virtual try-on experience sets the store experience apart from existing physical store options, as the process does not require the child to physically put the product on, and it removes waiting times that are usually a result of a store assistant going back and forth between the stock room to find the right pair of shoes in the correct size. This removes a lot of the friction from the selection process, and a large variety of styles can be assessed in rapid succession (see appendix E for illustrations of store interactions).

Figure 41: AR shoe projections made with Lens Studio by Snap AR

Figure 42: 3D visualization of Luca waiting for customers

Figure 43: 3D visualization of Luca interacting with customer

Capturing the correct physical fit data and making it easy to make an informed style choice are the most important drivers for the design of the proposed in-store experience. However, as shown in figure 42 and 43 , this approach also allows for additional storytelling elements that make the system come to life. As people have become detached from the manufacturing process of their products, valuing convenience and speed of delivery above all else, Luca allows users to engage with their personalized product in an entirely new way. The environment that Luca was placed in was strategically chosen to reflect the manufacturing process is a playful way. A series of 3D printers in the background show how the product is made, allowing the user to be part of the manufacturing process, making the end-product more personal, and possibly tapping into the imagination of the child. Furthermore, digital environments could be created for the child to be displayed in, as they are trying on different styles, adding to the imaginative store experience.

In conclusion, the proposed in-store experience is expected to remove a lot of the friction that is often associated with store visits, while putting the child at the center of the measurement and style selection process. Highly accurate foot and fit data are captured, which is essential for the creation of well-fitting, highly personalized footwear, and users can easily and accurately identify their style of choice. As the system detaches physical fit and style, the store experience is able to resemble the freedom of choice that is at the core of the experience at Ace & Tate. This hopefully counters the reasoning for parents to go online in order to access a larger variety of styles. Additionally, the story telling experience with Luca and projection of non-existing shoes onto the feet of the child allow the system to capture some of the Efteling magic. Together, this provides a store that is minimal in spacial foot print, and maximal in terms of available product and experience, which gives us: world's smallest biggest shoe store.

Mobile User Experience

In order to create a seemless and integrated omni-channel user experience, a mobile experience concept was designed to accompany the in-store service. The mobile service concept has two roles: assist users in the selection of new footwear and help users to create healthy footwear habits between store visits.

Even though the in-store experience has been designed to reduce friction throughout the measurement and style selection process, a webshop could still add significant value for users of this product-service system. Some parents, for instance, enjoy online shopping and might prefer to check the available styles and play around with color options before visiting the store (see figure 44). As discussed in chapter 3, the role of parent and child in the selection process of footwear generally changes over time. An omni-channel customer experience could lend itself to accomodate these changes. A digital product overview would allow parents to create a pre-selection of acceptable styles, to narrow down the options that the child may choose from during the in-store experience. Additionally, the ability to browse and create a pre-selection before a store visit is also likely to further reduce the time spent in-store, which is beneficial for parents who are short on time, as well as for the amount of customers that can be served with a certain period of time.

While it is important to create a highly accurate image of a child's feet when new shoes are ordered for the creation of well-fitting shoes, it is not enough to maintain a correct fit over time. As discussed in chapter 2, at any given moment, the majority of children is wearing shoes that are too small. This is a direct result of the simple fact that most children's feet grow over time. The speed of growth varies, depending on age. As parents have pointed out, this growth can be perceived as highly unpredictable, and a lack of parental consideration and communication with the child can result in a child wearing shoes that they have already outgrown for a significant amount of time, to the detriment of their foot health and development. Rather than waiting until the current pair of shoes hurts and child completely refuses the wear their shoes, causing parents to hurry to the store and buy a new pair of shoes, a new product-service system should be able to inspire and facilitate more proactive footwear consumption behavior to promote healthy foot growth. In two ways, Luca helps users to stay up to date on the child's foot growth and determine the right moment to order a new pair of shoes. Figure 45 shows an impression of a mobile foot scanning experience that can be used from home to determine the foot growth of the child and match this with the room that is left in their current pair of shoes. This would allow parents to actually look inside their child's shoes and clearly see how much room is left. Through periodic notificiations, parents might be reminded to update their child's foot growth record. Even though it was argued that mobile foot scanning solutions are not yet able to collect data that is sufficient for the creation of highly personalized 3D printed footwear, it is likely that mobile scanning solutions are sufficient for updating the model and to determine the best moment to go to the store for another full scan. The mobile scanning option could be found on the user's online account, which will also hold the information and, over time, create a complete overview of the child's foot development over the years, which is directly accessible by the user. In this way, Luca is truly able follow along with the user's footwear and foot development journey.

In addition to helping users to keep track of the child's foot growth through mobile scanning and updating fit data, Luca aims to help parent and child to become more aware of how their shoes fit and how their feet feel. Through periodic notifications, users could be reminded to consider these factors regularly. As shown in figure 45, a simple reminder such as 'Can Laura still wiggle her toes inside her shoes?' might be enough to nudge parents to considers the fit of their child's footwear more consistently and make foot health top of mind, in a non-intrusive and playful way. It helps parent and child to learn which questions to ask with regards to fit and foot health, potentially leading to more healthy footwear habits.

Figure 44: Visualization of digital product overview (Left: Reef; Middle: Nelly; Right: Wander)

Figure 45: Mobile LUCA interfaces (Left: Homescreen; Middle: Mobile foot scanning; Right: Fit reminder)

7.4 User Testing

This section provides a detailed explanation of the user testing that was conducted during this thesis with regards to the experience and service design part of the PSS. The research method, results and discussion have led to key takeaways and considerations for future development.

Introduction

In order to assess the current perception of the proposed customer experience of the product-service system and identify areas for improvement before market introduction, a series of interviews of interviews was organized with parents of children up to twelve years old. These interviews have provided important insights with regards to the current perception of the design omnichannel customer experience, providing clear guidelines for further service development in order to further meet the needs of the target user.

Research Method

The aim of this study was to gain an in-depth understanding of the initial reactions and feedback based on visual representations and verbal description of the designed customer experience for 3D printed footwear. This study was part of the same study that was previously described in Chapter 6.3 'User Testing'. After an introduction and discussion about the physical product described in Chapter 6, the customer experience was presented and disucessed with each of the participants. Further details about the setup of this study can be found in Chapter 6.3. The following research questions were formulated for this part of the study:

RQ1: How desirable do parents consider the proposed retail experience?

RQ2: To what extent do parents expect the proposed retail experience capable of providing them with children's footwear with a good physical fit?

RQ3: How desirable do parents consider the design of the additional mobile service for foot development and fit tracking?

RQ4: To what extent do parents consider the product-service system more or less sustainable than available children's footwear solutions.

RQ5: To what extent would parents consider second hand product options in the proposed product-service system?

RQ6: To what extent are parents willing to use and pay for LUCA?

Results

The audio recordings and written notes that resulted from the conducted interviews were analyzed and common themes were identified.

Location & Assistance

Participants noted that placing the shopping stations in locations with a nice atmosphere and associations with expertise and quality are more important than trying to place the shopping station everywhere.

"Stores where you know that quality shoes, sometimes with a higher price, will be ... I think you should place the product and service somehwere where you know people go for quality ... I wouldn't just place [the shopping stations] everywhere ... Your reputation and believability is important" - p5

Additionally, several participants mentioned a need for human store assistance, especially because the product is new and unknown. Additionally, store associates are considered useful for additional service providing and making sure that the shopping station is clean at all times.

"Maybe self-service if it was an established brand. Otherwise, someone to just kind of 'be a human' ... Like, how would you get people to know, until you have a person ... I don't think you can start something new like that without a human" - p2

In-Store Measurement Experience

Most participants considered the in-store foot measurement process with Luca desirable and expected this process to be understandable, engaging and fun for their child. This was true for different genders and age groups. One parent, however, noted that it could be good to further tailor the character (Luca) to the gender or age of the child.

"My daugther would enjoy [the store experience] ... I think everything together, it is a nice experience for them. It gives buying shoes something extra" - p1

"[My daughter] would really enjoy this. I think every two-year-old could do this. Before then you don't understand what is happening, and then she probably doesn't have the patience, but now she would find it very interesting" - p3

"[My sons] would definitely like the idea. You would probably want to think, from a branding point of view what kind of character and what kind of setting ... With little kids, it's hard to tell sometimes, but have one for boys and one for girls so they can choose or the parent can choose ... Maybe something with a dragon, or a robot? Kids like robots" - p2

Multiple parents also noted the use of giving the child something physical or digital at the end of the store experience to keep it concise and deal with the fact that the child does not immediately receive their shoes.

"The coolness of the machine, that's cool, that's probably the first draw ... As a parent I could be like 'I can entertain them', even if it's shortly, I can make this 'being out thing' fun, for both of us. We like to see our kids have fun. Like 'Hey look! Go into the rocket ship!' ... And if it's cool enough you might even get them to stand still, because they are looking at something cool ... Kind of like a photobooth. People do that because it is fun, and it creates a memory. This is fun and it creates a very perfect shoe. But fun in a very concise way and then keep it moving ... Have it dispense a sticker at the end or something" - p2

"But then of course children have to wait until they are printed. Do they get something temporary, like a piece of paper or something?" - p7

One of the participants explicitly did not believe a store experience was necessary for taking foot measurements such as foot length and width and insisted on doing this from home with a phone.

"Way too difficult. You should be able to do that at home. Then you really have added value" - p4

Magic Mirror Experience

The AR mirror experience was considered desirable by most parents for its ability to make it easier for both parent and child to imagine the product on the child's feet. Additionally, most participants considered this experience engaging and fun for their child.

"This is super cute! This would surpass a five star review. You can immediately see how the shoes look on you." - p5

"That's pretty cool. I think especially for children, that's kind of an almost magical thing" - p6

"I think if you show that to a child, it will definitely help someone to buy it. The child will think 'Wow, that's awesome, I want that'." - p4

One participant was suprised about the shape of the barefoot shoe when it was displayed on foot through the Snap AR prototype, as it differed from the impression she had based on previous images.

"Which ones are these? They look very round ... Unless it's just not showing very well. From this angle it looks like it's going to be a very round ... Like a clown's shoe! ... So if that's what it looks like in real life, [my kids] might be like 'okay, that's not what I thought it was' and we would just return it" - p2

Four participants directly highlighted their excitement about the ability of the proposed customer experience to involve their child more in the selection process and create a product that is truly "theirs". These participants are currently primarily buying children's footwear through e-commerce.

"I really like that you include the child in the purchasing process. I don't do that myself now, but I think it would be a lot of fun. My child would certainly enjoy that very much. And that she has her own shoes. Then that shoe also becomes more important ... That you simply include the child in the choice and that as a parent you get the feeling that you don't have to figure it out all by yourself. Because I found that quite complicated, how to do that. You have no experience buying shoes with your first child." - p3

However, one of these also noted she does not always consider it necessary to have her sons part of the style selection process directly.

"Make this kiosk quick to get [children] in the system, and if they have time, they order it and create a profile. If they don't have time, it will email them to create a profile at home and then select what kind of color and type and all that. And I don't feel like I would need my kid to be standing at a kiosk seeing how it looks on them, unless I had time ... I just choose for them most of the time." - p2

Additionally, one participant noted that the AR mirror experience might not be fully understood by her daughter of nine months yet.

"I don't think she really realizes that yet. Sometimes we stand in front of the mirror and she is laughing at herself ... But I don't think she really realizes what she is wearing in detail. I think that will take a while. Six months or so." - p6

Multiple participants expressed concernes about waiting times at the shopping station due to other users taking a long time with the style selection and mirror process.

"So if I went into a store, if I was going to the kiosk, there would need to be enough kiosks, so I would not be just having to wait there with my child, because children are very annoying when they are waiting" - p2

In order to prevent choice paralysis and limit the amount of time spent in-store, it was considered desirable to have access to an online overview of the available styles to browse and select from. It was also mentioned that the amount of available different styles should be limited in order to make the style selection process easy for both parent and child.

"If you don't offer much, this makes it easier of course. The choice is limited. You don't have an endless supply of these types of shoes, so that's nice ... Especially if you include the child in the selection process, it is nice not to have too many options. Otherwise they won't know anymore either. " - p3

Acceptable Delivery Time

The acceptable delivery time varied strongly amongst participants. While some parents considered a couple of weeks still acceptable for personalized 3D printed children's footwear, others found this highly undesirable and expected a delivery times of a few days maximum.

"I think six weeks. Why six weeks? Because that is how long I had to wait for [my daughter's] [orthopedic] shoes ... For custom made shoes, I can wait. It's your choice if you want to wait or not." - p5

"I would be okay with coming back the next day or a week later. I think if it's more than a week, it would probably be too much of a hassle" - p2

"I think two weeks is quite a long time, but that's still acceptable" - p3

"I think four to five working days. Often when you order a pair of shoes, you need it quickly, because the other [pair of shoes] is too small." - p1

The desire for fast delivery times was related to growth of the child's feet, and the fact that shoes were generally bought "too late", which made instant delivery of replacement product needed.

"I usually find out too late that a new size is needed, so then you suddenly need a new shoe" - p3

On the other hand, one participant also noted that she thought there was a possibility to for the company to use the waiting time as part of the experience.

"If you can think of something that can easily generate 'a few days' or 'this is happening now' or 'it will come to you later'... Then you make it a lot of fun. That journey then goes on" - p7

Mobile Customer Experience

The ability to update a child's foot and fit data from home through mobile scanning was generally considered desirable by participants for its capability to help track foot growth and buy new footwear in time. However, monthly scanning was considered undesirable. Participants wanted to only be notified by the system and create a mobile scan if it their child was expected to soon need another size.

"During the holidays, when I didn't expect it, her shoes were too small. From one day to the next, she could not fit into them anymore." - p1

"Or just like: 'According to our expectations it is time to measure again whether the feet have grown', you turn it into a kind of game ... Then you immediately have a hook to connect nice shoes to it... Every month is a bit much in terms of frequency" - p4

"And, like, remind me 'okay is it time for a new scan'. Like remind me to come back to the store for a good reason ... Alert me in six months or something like that." - p2

One participant noted the importance of such additional services for brand image.

"It would be a nice service, and it would also tell me something about your brand, that you really care about the wellbeing of people's feet." - p5

Additionally, one parent highlighted a desire for the system to allow additional purchases through the mobile service directly, within a given time period after the in-store scan. Additionally, it was noted that she would enjoy the process of checking out different style at home with different outfits for her child.

"I would spend way more time customizing it too, potentially, and getting their clothes, and be like 'too bright' or get a different blue or something ... Online is way better ... But the [in-store] scan though. That's cool. That's great!" - p2

Membership & Subscription

During this study, multiple participants have put forward the idea of turning the product-service system into a subscription model. The idea of being a member and having a shoe account that grows with you and makes sure your child always has the right size was considered desirable.

"I am a profile in your system now, like 'this is my shoe account' ... Yeah you want to make [users] a member if this is what you are doing." - p2

"I would also think that it is almost a kind of subscription, like 'Hey the kids are growing so fast that you need a new shoe every time', that you get a reminder of 'Hey it's time to choose'." - p4

However, some participants have noted the unwillingness of some parents to sign up and create an account for other products and services in general.

"I quite like it when you don't have to fill out a whole form and you can also place an order as a guest" - p7

Need for Proof of Concept

Endorsement and recommendation from other people who have used or tested the product played an important role for parents, as this would reduce risks for spending money on something that might not work. And while participants did like the innovative aspect of the system, they did not like the feeling of having their child be part of an experiment.

"If I would hear that the shoes are really good and are really recommended, then I would be willing to go to the store for that ... Mostly [recommended by] friends ... but also online" - p1

"For me personally, I think it would be that other parents have said 'these are nice shoes and the process works very well'." - p6

Ability to Provide Physical Fit

Most participants were confident in the system's ability to provide them with shoes with a personal physical fit.

"I expect that it can be done very accurately with such a measuring system" - p3

Multiple parents have also mentioned the need for guarantees, as buying without trying is still considered risky. Additionally, it was mentioned

that a perfect fit does not necessarily mean the child will like the “feel” of the shoe.

“I assume you have the ‘money back’ guarantee... Then you are willing to take the risk” - p4

“I think you are taking a gamble, if I am honest. Like is it comfortable for the child?” - p1

“A four year old.. Is that going to cause a problem when we get the shoes, is that going to be like a poor fit? That would have to be clear like.. Keep them as still as possible, like for three seconds as still as possible ... But if that’s not the case, I would not take the chance with a four year old” - p2

One participant directly considered the system more convenient than existing online and offline shopping solutions, with regards to finding the right size.

“I always find buying shoes online very difficult, because they always vary greatly. Size 45, then you buy that size, but then it is still too small. That’s why it’s useful to be able to try it on, but I can also imagine that trying on shoes with children isn’t much fun, so I think a [scanning device] like that is easier than, say, trying on ten pairs of shoes.” - p6

Another participant noted a desire to also receive detailed size information that could be used to buy well-fitting shoes in other places.

“Once you do such a whole measuring process, it is nice to have some kind of outcome, that you immediately know ‘my child has this size’. Then you also get some information, for if you want to different kinds of shoes. That’s an extra, then you are sure of your child’s size. Now I always guess a bit.” - p3

Take Back System

Participants are generally excited about a take back and recycling system. Providing users with store credit or discounts on future products was considered an important driver for repeat purchases and becoming a member.

“I think it is an advantage if you can take [used shoes] back to the store and then get a twenty percent discount, for example” - p1

“For the recycling thing, you bring it in and you get a discount on the new pair. That works. That’s enough to make someone come back. Or get two, because two different colors, or two different styles” - p2

Returning product to the store during a next visit was considered more desirable than sending it back to the company.

“Very tangible, that you can see it ... as you have in this photo, that you have such a container where it ends up in, I think that is a very nice idea. I would not ship them ... that takes too much effort in my opinion.” - p3

One participant wanted to throw the product in his trash can for plastic waste at end-of-life, assuming that the general recycling stream would be able to process this.

“The municipal systems, I think they can remove plastic quite well these days. I don’t know about this material for recycling. I would prefer to just throw it in the trash, with the belief that this will be recycled automatically.” - p4

Price Expectations

With regards to the willingness to pay, participants generally expected the price of the product to be similar to available children’s footwear options.

“I wouldn’t assume it costs less because it’s ‘custom made’ and ‘one of a kind’, but I also wouldn’t assume it costs more because you don’t have stock ... Intuitively it feels on par with other children’s shoes.” - p4

“Forty? About forty bucks for a kid’s shoe. Which is usually around half the price for an adult’s shoe for like a decently known name brand.” - p2

“I [would expect to pay] 60 euros, I think ... I had bought water shoes at Decathlon recently, those were 10 euros.” - p1

Furthermore, the willingness for multiple participants was dependent on their child’s foot growth.

“If it was a hundred euro’s.. It needs to be cheaper be cheaper for a very small toddler, because their feet do grow pretty quick ... If the price looks cheaper, but if the price looks the same for a baby size shoe, compared to a five year old shoe, in my brain it’s like ‘I will wait until they are bigger’.” - p2

Sustainability

Fully 3D printed children’s footwear was generally considered more sustainable than available solutions, due to the mono-material construction allowing for better recycling, and the elimination of waste that is currently associated with overproduction.

“A shoe like that seems to me to be ideally something that you can actually return to the store, because I think the material is very recyclable, isn’t it? You don’t have to take anything apart” - p1

“I think it is made of one material and is therefore 100% recyclable, which appeals to me. It would also be quite nice, I don’t know to what extent that would be possible, but that you could also hand in your own shoes and turn them into a new shoe that you can wear again.” - p6

“More [sustainable]. Because it is ‘one of a kind’, so there is no overproduction” - p4

Second Hand

Highly personalized, printed children’s footwear was generally considered not fit for reuse, and almost none of the participants would realistically consider buying this product second hand. The promise of a highly personal fit was in direct conflict with the idea of reuse and buying second-hand.

“No, because you say that it is completely custom made, so I don’t think I would buy a shoe like that second hand” - p1

“It depends a bit on whether it is made completely to your foot. Then I would quickly have the idea that it was made for a different foot and that it wouldn’t fit quite right ... I don’t think I would do it.” - p3

“I feel like a lot of people just don’t want pre-owned, unless they are searching for a bargain. And those who are searching for a bargain, usually don’t get a well-branded shoe ... ‘Personalized’ is a big deal man. You don’t buy ‘pre-owned personal’.” - p2

“If you were to ask me now ‘would you do that?’, I would think ‘of course I should do that, but I wouldn’t do it’ - p7

Additionally, the pricing of a reused pair would need to make sense, compared to a new pair.

“It would have to be a drastically lower price to be worth considering ... There is a threshold, right, where you are not even going to consider pre-owned, because the price is already decent for a brand new” - p2

Discussion

In-Store Experience

This study found that the design of the in-store shopping experience was generally considered desirable by most participants, and expected to be interesting and engaging for children up to twelve years old. The foot scanning sequence guided by Luca was expected to provide a convenient measurement experience, and trusted to provide data that would lead to the creation of well-fitting footwear. Additionally, it was stated that such the AR mirror experience would be beneficial for both parent and child, as it would likely allow for a easier and more accurate assessment of product style and styling potential than existing online commerce for children's footwear. It should be considered, however, that for the youngest users of the system, the mirror experience might not be completely understood, as one parent noted that their daughter of nine months old did not yet fully grasp the concept and detail of what a mirror was. This insight aligns with existing literature that describes the gradual development of a child's self-awareness and understanding of mirrors and reflections in the first four to five years of life (Rochat, 2003). Future product development and research should further explore the understanding and interaction of such an AR mirror for children's footwear. Additional research directly involving children is needed to further understand the desirability of Luca and his environment, as well as the physical scanning platform, among children of varying ages.

The ability of the in-store retail experience to engage and put the child at the center of the scanning and selection process was considered both highly desirable and highly undesirable participants. Multiple participants expressed great excitement about the possibility to further include their child in the footwear selection process, and noted that it would provide a product that feels more like "their" shoes, possibly leading to greater attachment and willingness of the child to use the product. On the other hand, two parents expressed their unwillingness to participate in the full store experience, due to their preference to choose children's shoes by themselves, or because of a believe that highly accurate foot scanning should be possible from home. Based on the conversation, the latter seems to be strongly influenced by the parent's confidence in (using) technology, as well as the age of the child. It was noted that with younger children, there might be a risk of inaccurate scan results, due to the movement and inability to stand still for extended periods of time at this age. The study suggested that such perceived risks and uncertainty about the accuracy of a foot scan, especially with younger children, might be a barrier for parents to place an order. As the mobile service experience also requires mobile foot scanning, future research and development of the system should focus on the success and failure rate of in-store and mobile foot scans with children of different ages.

Furthermore, future development of the in-store experience should consider providing the child with a physical or digital gift at the end of the shopping experience. This was suggested by parents as it would help in keeping the shopping experience concise, as it provides a clear end to the experience for the child, and it might be useful as the child does not immediately receive their shoes at the end of the experience. This suggestion of parents aligns with the peak-end rule proposed by Kahneman (2012). Making sure that the end of the in-store process is experienced as positive by the parent would likely significantly affect their memory of the experience, and in turn their willingness to repeatedly engage in it.

While the accessibility of shopping stations is important for users to consistently engage and stay part of the system, this study found that it is important to strike a good balance between the accessibility of the shopping stations, and the quality and consitency of the experience. The study suggests that investing in a consistent and high-quality experience is required for parents to engage with the system, and that there is a willingness to travel a greater distance if a good experience is guaranteed. Additionally, introduction of the system should consider the role of the human retail assistant, as the study found that this could be highly important to overcome the novelty of the brand and system, and increase awareness of the availability of the service. For succesfull market introduction, further consideration is needed to determine desirable locations of the shopping stations, and the amount of human assistance required.

Online Pre-Selection & Shopping

With regards to the style selection and shopping experience, the study found that is was desirable to allow users to browse and pre-select styles before attending the in-store experience and complete the order. This could benefit the convenience for parents, and facilitate the changing role of parent and child in the footwear selection process that was first discussed in chapter 3 of this thesis. Additionally, the option to create a pre-selection could reduce the amount of time spent at the shopping station. This would be important, as participants noted their unwillingness to wait at a shopping station, as waiting with children was considered highly inconvenient. Future research and development might address this by considering ways to physically detach the style selection from the foot measurement process, as the current design causes a need to wait for current users to complete the entire process, before a next user is able to engage with the scanning process that takes a couple of seconds. This, however, depends on if it is desirable to allow users to only use the foot scanning sequence, and place an order online. As stated before, consideration and careful curation of the style offering is also needed to help users make a decision.

While the goal of the shopping experience is to put the child at the center and allow them to be part of the style selection process, the need to visit a physical retail location for every order a user wants to place might not work for most users. Based on user feedback in this study, future development should consider the ability of users to place additional orders online within a given period of time after a physical store visit. To increase chances for the child to be engaged online, the AR mirror experience might also be translated into a mobile virtual try-on. Further testing with parents and children is needed to understand the interactions that such features would bring about and the role of the child in the selection process. Additionally, it raises the question of whether or not children must be part of every selection process, or if their direct involvement once a year, for instance, would be sufficient to allow the child to develop and communicate their developing style and taste with regards to footwear. Overall, the study suggests that the system should be flexible and allow parents to use the physical in-store and mobile store aspects in the sequence and to the extent that works for individual users. This finding aligns with the information discussed in the first section of this chapter, that describes how omnichannel user experiences should allow users to make use of the different physical and digital touchpoints in a way that fits their values and schedule.

Physical Fit

This study has also touched on the subjectiveness of physical fit and comfort, and the challenges that this brings for the creation of personalized footwear. One participant expressed their confidence in the system's ability to provide well-fitting footwear, but also expressed their uncertainty about their child's willingness to wear the product, as she considered a 'perfect fit' not a guarantee for a desirable wear experience for the child, as this is also impacted by the material and texture of the product. Another parent had similar concerns with regards to the possibility to wear fully 3D printed shoes without socks. While the participant would like for their children to use the product without socks, there was also a perceived risk of causing chaving or blisters on the child's foot. Therefore, future research and development requires thorough user testing to create a product that fits well and feels comfortable for children in daily use.

With regards to the output of the system, one parent asked whether the fit data of her child would be translated into common shoe sizing information, as this would help her to buy well-fitting shoes from other brands in the future too. This finding highlights a risk of the proposed PSS. An automatic scanning and measurement process might make parents and children even less knowledgeable about the child's shoe size. When using the LUCA system, this would not be a concern, as the system determines the correct size, but this does make it even harder for parents to buy well-fitting footwear in other places. The design of the system should therefore consider ways of making it easy for users to access clear fit information that also empowers them to make healthy footwear choices in other places.

Membership

During this study, multiple participants have proposed the idea of turning the proposed product and service into a membership and subscription model. The convenience of always having the right shoes for their child at the right time, and being part of a system that grows with the users, was considered highly desirable. Excitement was expressed about a mobile service that could provide a reminder to check the child's shoe size, and the ability to easily place a new order for the next pair of shoes. The study suggests that, in combination with potential discounts upon return of used shoes, a membership and subscription structure could be applied to the proposed product-service system for 3D printed children's footwear. With regards to the frequency of alerting parents to check on their child's size, participants did express unwillingness to engage in consistent mobile foot scanning. Rather, it was suggested repeatedly that the service should only remind the user when it is likely that a new pair of shoes is needed. Future research should determine if mobile notifications as described in chapter 7.3 ('mobile user experience') can be an effective way to still promote consistent checking and encourage pro-active footwear consumption.

Delivery Time

The delivery time of purchased products will be a critical success factor of the system, and an important determinant for the user segment that decides to engage in this system. While for some participants, anything more than a couple of working days is considered unacceptable, the study suggests that for most parents, the need for fast delivery of children's footwear is mostly related to the parents' experience that shoes are always bought when a child's current shoes are already too small. Other than this, participants reported acceptable waiting times ranging from one to multiple weeks for custom made footwear. System development should focus on finding out if the mobile service of Luca can sufficiently help to promote more pro-active footwear consumption, and if current foot growth prediction system can provide usable results. Additionally, a general reduction of the waiting times currently associated with 3D printed footwear is a critical success factor, as current waiting times of approximately five months at Zellerfeld would not be sufficient to propose such a system for children's footwear. However, since the speed of production is directly linked to the size of the 3D printed object, significant reductions in waiting time could be expected with children's footwear, compared to adult sizes. Furthermore, the consistency and predictability of children's footwear replacement might provide additional opportunities to better project and organize production to fulfill orders. Finally, market introduction requires a strategy that carefully considers the target segment and limits the amount of users in order to make sure that orders can be fulfilled within an acceptable timeframe.

Pricing

Careful consideration of the target segment is also needed in relation to price expectations and willingness to pay for personalized 3D printed children's footwear. The study suggests that parents are generally expecting to pay the same amount of money for this product as they would for other children's footwear, and generally of half of the price that is paid for adult shoes. This, however, means that the price of 3D printed footwear could be anywhere between ten euros and eight hundred euros, depending on the frame of reference. For market introduction, it should be considered how the system can be put into a category of one, and prevent direct comparison with other or cheaper children's footwear. In addition, the pricing strategy should consider the lower willingness of parents to pay for shoes of younger children, due to the rapid product replacement rate as a result of foot growth.

Sustainability

With regards to the sustainability of the proposed system, this study suggests that parents perceive the system as significantly more sustainable than existing solutions for children's footwear, because of the possibility for effective and efficient recycling of the product at end-of-life, as well as the reduced waste that results from on-demand production. However, the study also found significant tension between the promise of 'personalized fit' and the idea of using pre-owned products. Even in a scenario where the system purely matches users with the right standard length and width sizes, the conflict in perception of both promises could not be overcome, as participants still did not consider the reuse of this product desirable for their child. Furthermore, reducing the promised level of physical fit personalization would possibly decrease user's willingness to pay, and further using testing is required to determine the level of personalization that is actually needed to make the product functional. Therefore, future system developments do not only require the creation of efficient end-of-life product collection and processing infrastructure and logistics, it also requires a strategic choice about the amount of product customization that is provided to the user.

Another consideration with regards to sustainability of the system and successful end-of-life processing is the need to inform users of the best way to dispose of the shoes, as one participant noted that he would likely throw fully 3D printed shoes together with generic plastic trash at end-of-life, as he believed that municipalities should be able to separate it from the waste streams and recycle it. In general, participants were found to be most interested in the possibility to return the shoes to the physical point of retail, in case they would order a new pair of shoes, or in the possibility to throw it in the general clothing of footwear collection bins. Return shipments were generally considered highly inconvenient and time consuming.

Risks and Guarantees

A final topic for this discussion section is the need to overcome parents' perceived risk and feeling of having their child being part of something 'experimental'. While some people might enjoy the system's novelty, the practical use and positive impact on foot health needs to be proven in some way, to overcome cost and health associated risks. Future development could focus on money back guarantees, as well as providing recommendations from professionals, foot health authorities, and other users of the system.

Key Takeaways & Design Considerations

- The in-store foot scanning and style selection process was generally considered desirable by parents in this study.
- Parents have trust in the system's ability to provide a perfect fit, but there are still concerns as a perfect fit does not guarantee that the child will enjoy the feel of the shoe.
- The AR mirror is expected to allow for accurate assessment of the product by parent and child, but further research is needed to determine if children of every age up to twelve years old are able to comprehend the experience.
- Further testing with children is required to determine the desirability of the Luca character and the scanning platform, and confirm whether the intended interactions are achieved with the current design.
- Future development should determine the amount of time that customers will spend on the shopping station, and consider a design that minimizes waiting times.
- Aligned with the 'peak-end rule', providing the child with a small gift to mark the end of the in-store process could keep the experience fun and concise, and increase willingness of parents to repeatedly engage with LUCA.
- Personal fit information should be translated into easy to understand sizing information for parent and child.
- A consistent and high quality store experience is considered more important than having shopping stations everywhere.
- Human assistance at the shopping station would be required for successful market launch, to make people aware and help people to use it.
- Business development and pricing strategy should be based around a membership and subscription model.
- Accurate foot growth prediction and discounts on additional purchases are considered great incentives for parents to stay part of the system.
- Increased speed of production, the system's ability to promote more pro-active consumption behavior and prediction of the footwear replacement rate are essential to fulfill orders from members in time.
- Choosing the right target segment and putting the PSS in a 'category of one' are important to charge a price that can cover the cost of fulfillment.
- The pricing strategy should consider the relation between a child's age, rate of foot growth and the parent's willingness to pay.
- Certifications and testimonials from health authorities and other users are important to gain trust from parents and overcome risk perceptions related to the novelty of the system.
- Some parents believe that buying children's footwear can become a highly enjoyable family activity, through a system like LUCA. Others are only interested in solutions that make it as convenient as possible for the parent. The latter group is not the target group of the proposed PSS.
- User testing suggests that the willingness to use pre-owned footwear from LUCA is significantly lower than with existing children's footwear solutions. This is due to perceived conflict between the promise of 'highly personalized fit' and the associations with 'pre-owned'.
- The PSS is considered significantly more sustainable by parents, as a result of the product's recyclability and the reduction of waste through on-demand production.

08

Market Introduction Strategy

This chapter describes a market introduction strategy that was developed for the proposed product-service system for 3D printed children's footwear. First, the target segment for market introduction, market positioning and pricing strategy are detailed. Thereafter, an overview of the system and the key activities is provided, and strategic partnerships for the realization of the PSS are explored. Finally, this chapter introduces next steps for further product development and provides a timeline of activities, risks and key milestones until product launch.

8.1 Target Segment & Pricing Strategy

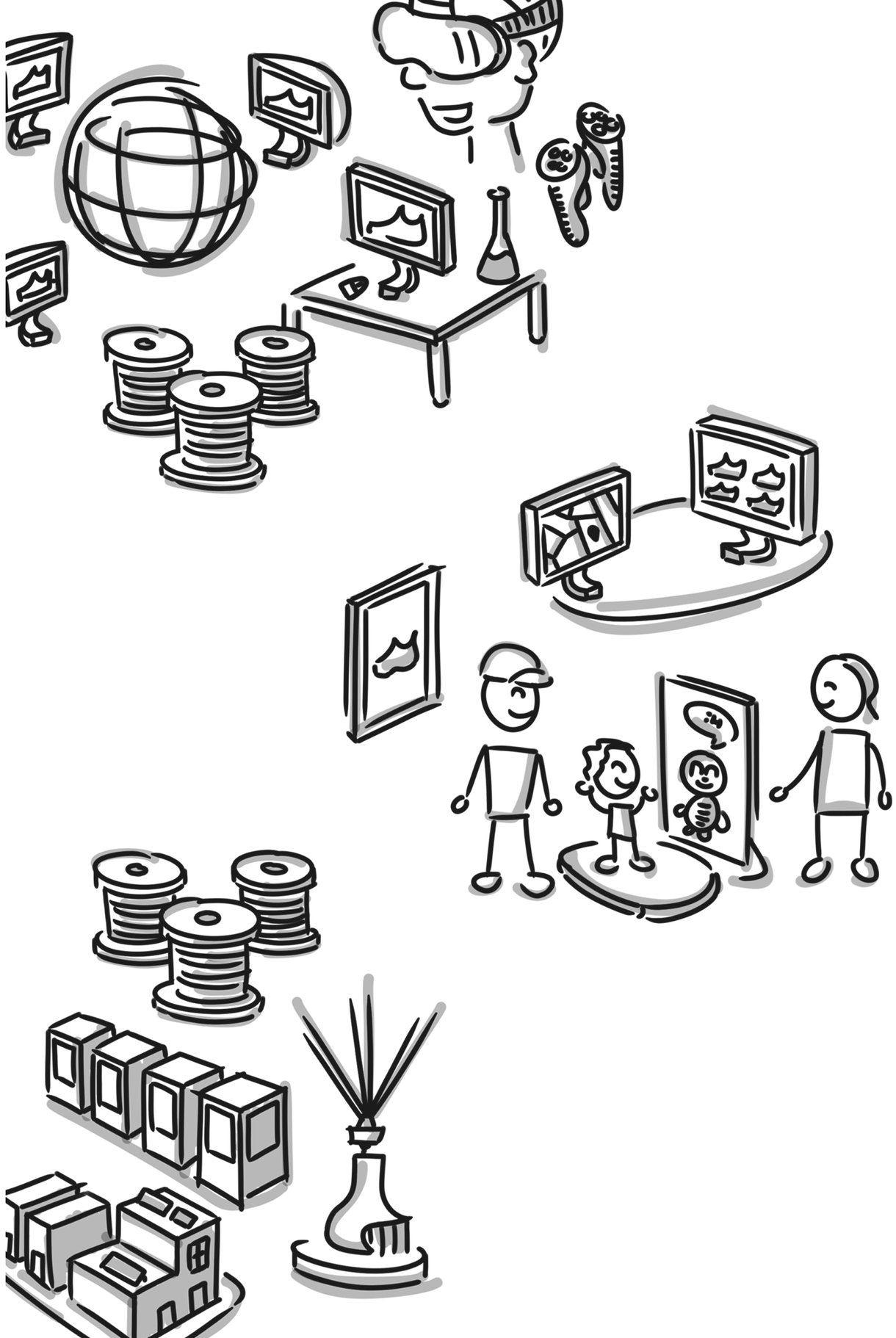
Beachhead Market: Upper Middle Class, First-Time Parents
Business Model
Pricing Strategy

8.2 Key Activities & Strategic Partnerships

Design & Development
Measurement & Style Selection
Sourcing & Manufacturing
Product Distribution
Product Use & Maintenance
End-of-Life
Marketing

8.3 Implementation Timeline

Creating an Audience
Forming Key Strategic Partnerships
System Development
Pilot
Launch
Risks & Considerations



8.1 Target Segment & Pricing Strategy

This section describes a market positioning and target segment that was chosen as beachhead market for the introduction of the designed PSS for 3D printed children's footwear, and it details possible pricing strategies.

Introduction

In order to create a to-market strategy, a beachhead market has to be defined within the broader target group of parents with children of up to twelve years old. The goal of this strategy is to define an initial target audience to serve, before trying to expand and advance into adjacent markets (Coelen, 2023b). Such an early market should consciously be experiencing the problems which the system is trying to solve, and these target users should be actively looking for solutions. Additionally, these users must want to see their problems solved or desires fulfilled in a novel way (Coelen, 2023a). Based on findings through the exploratory research detailed in chapter 3, and user testing of the concept in chapter 6.3 and 7.4, this chapter provides a description and visual overview (see figure 46) of the characteristics of the beachhead market segment, and a target segment to serve in the future. In addition to this, possible pricing strategies are described that are aligned with the PSS and target segment, and support the creation of a membership and subscription based PSS for 3D printed children's footwear.

Beachhead Market: Upper Middle Class, First-Time Parents

Willingness to Pay

The first step in the selection of a beachhead market is to choose a customer that has enough money to afford what they are being sold (MIT Bootcamps, 2016). As a result of the price associated with 3D printing, and the level of service that is provided to the user, the proposed PSS takes on a more premium or luxury market positioning. A look at the broader luxury fashion market reveals that the customer segment most responsible for spurring the growth of luxury brands like Louis Vuitton is the upper middle class. In an interview with Financial Times, Jean-Jacques Guiony, chief financial officer at LVMH, states: "We don't sell [most Louis Vuitton] products to rich people, it is the people who have money and want to indulge themselves ... The advantage is this cohort is much, much bigger than the super wealthy. We think the upper middle classes will continue to prosper, and we will tailor products and marketing to them." (Klasa et al., 2023). Therefore, the beachhead target segment of the proposed PSS will mainly consist of customers that belong to the upper middle class. Additionally, first-time parents are considered of special interest, due to many parents' tendency to spend far more on premium products for their first-born child compared to their second child (Ergobaby, 2019). Notably, the importance of child related spendings and feelings of parental pride surrounding this type of consumption are supported by findings from previous research, noting that lower-income families spend disproportionately more on children's products compared to wealthier ones, even in times of budget constraints (Pugh, 2009).

By providing a premium system that helps new parents to grow into their new role and provide their child with the best footwear, the proposed PSS will focus on first-time parents belonging to the upper middle class. Furthermore, the unwillingness of parents to sacrifice child related spending increases chances of customer retention, even in times of budget constraints.

Digital Accessibility

Within the 'upper middle class, first-time parents' segment, the proposed PSS is focused on customers that are accessible and reachable by the company. Most importantly, this means that customers are digitally active and reachable. Through exploratory research, detailed in chapter 3.1 of this thesis, it was found that parents are increasingly influenced by social media in their footwear consumption, as it provides many footwear options and makes information

Figure 46: Visualization of target segment characteristics

around children's foot health accessible and fun. The consumption and creation of digital content makes this target segment easier to reach through digital marketing. Furthermore, the online and social media activity of parents can be leveraged in the form of user generated content: original, brand-specific content created by customers and published on social media or other channels (Beveridge, 2022). This creates digital word-of-mouth that could benefit reach and awareness of the brand, especially in early stages.

Strong Reason to Buy

Third in the selection of a beachhead market is choosing a customer with a strong reason to buy (MIT Bootcamps, 2016). This includes customers that have actively experienced problems that the proposed PSS aims to solve, and are looking for solutions. Through exploratory research described in chapter 3.1, and user testing detailed in chapter 7.4, it was found that parents vary in their openness and willingness to engage in new solutions for children's footwear. This openness towards new solutions like the proposed PSS was dependent on two factors: 1) the parents experience with children's footwear, and 2) the challenges a parent had previously experienced with regards to finding fitting children's footwear. The studies in this thesis suggest that young, first-time parents are likely to be more interested in a new PSS for children's footwear, as a result of the lack of confidence in their own ability to provide their child with appropriate footwear that is good for foot development. Furthermore, parents that had direct or indirect experience with orthopedic footwear and orthotics were found to be highly interested in the idea of a personalized 3D printed footwear service, as it was seen as a major leap forward compared to existing solutions. However, creating orthopedic solutions, ranging from personalized ortopedic footbeds to fully orthopedic footwear, would require direct collaboration with professionals and institutions, as there are strict rules and regulations that apply to the creation of such products. It is, however, part of the mission to create a truly inclusive footwear system. Therefore, figure 46 shows that this is a future target segment that the proposed PSS aims to serve.

By designing friction out of the shopping process for children's footwear, the PSS was also found to cater towards parents seeking new solutions that provide convenience and save time (see chapter 7.4). However, as described in figure 46, the system does not aim to serve parents that put their own need for convenience and speed over the child's ability to be part of the process and find an optimal fit. Rather, the proposed PSS aims to remove certain points of friction from the current online and offline consumption process for children's footwear, and provide a more convenient solution for those who believe that buying children's footwear together with their child can be a highly enjoyable experience.

A Complete Solution

The proposed PSS aims to offer a complete solution for children's footwear that grows with the users and promotes healthy foot development in the first twelve years of life. The current ability of the system to fulfill this promise is, however, tied to certain geographical restrictions. First of all, user testing of the physical product, as detailed in chapter 6.3, suggests that fully 3D printed children's footwear is not perceived as suitable for cold weather conditions. Therefore, if this product characteristic initially stays the same, the beachhead market segment should be further specified to geographical locations that provide weather and environmental conditions that suit the characteristics of 3D printed footwear year-round. Furthermore, as the PSS is highly reliant on people's access to physical points of retail, the beachhead market segment should be further specified to densely populated areas that ensure sufficiently high traffic through each of the shopping stations.

Competitive Landscape

There are currently no direct competitors for a system that provides 3D printed children's footwear that grows with its users. However, from the customer's point of view, there is a very large number of children's footwear brands to choose from. This includes quantity and performance oriented brands like Nike, Adidas and New Balance, and premium or luxury brands that one may find during a visit at Bijenkorf.

Finally there are brands like Vivobarefoot, creatin children's footwear with an absolute focus on foot health. None of these brands, however, create a complete end-to-end product-service system that grows together with its users and provides a more convenient and highly personalized product and service experience.

Scalability

A more premium and luxury positioning of the PSS is chosen, partly as a result of the cost of 3D printed footwear and the services that are provided, but also for other strategic reasons. The positioning aligns with the pricing strategy and high-end fashion collaborations from Zellerfeld (see figure 47), that help increase the general desirability and status associated with fully 3D printed footwear. Removing direct associations with water shoes and Crocs, as described in chapter 6.3, is essential to create a product that is considered desirable from a symbolic and aesthetic point of view. Positive product perceptions and associations are required to eventually scale into other market segments.

Consistency with Brand Values

A final factor in the definition of a beachhead market is the market segments alignment and consistency with the core values of the brand (MIT Bootcamps, 2016). The following values can be found in parents who are part of the beachhead market of the proposed PSS.

Tech-Integrated & Health Focused: With parents and children increasingly becoming digital natives, and ownership of digital devices growing worldwide, barriers to adoption of a PSS that relies on the use of such devices is rather low with an envisioned beachhead market of young parents (Stalker et al., 2019). Furthermore, technology is increasingly being used by today's generations in order track and improve their personal health. As the new PSS promotes better footwear and foot health habits through technology, the system is for those who are aligned with market trends towards technology supported health, and are looking for lifestyle based and preventive approaches to health care for themselves and their child.

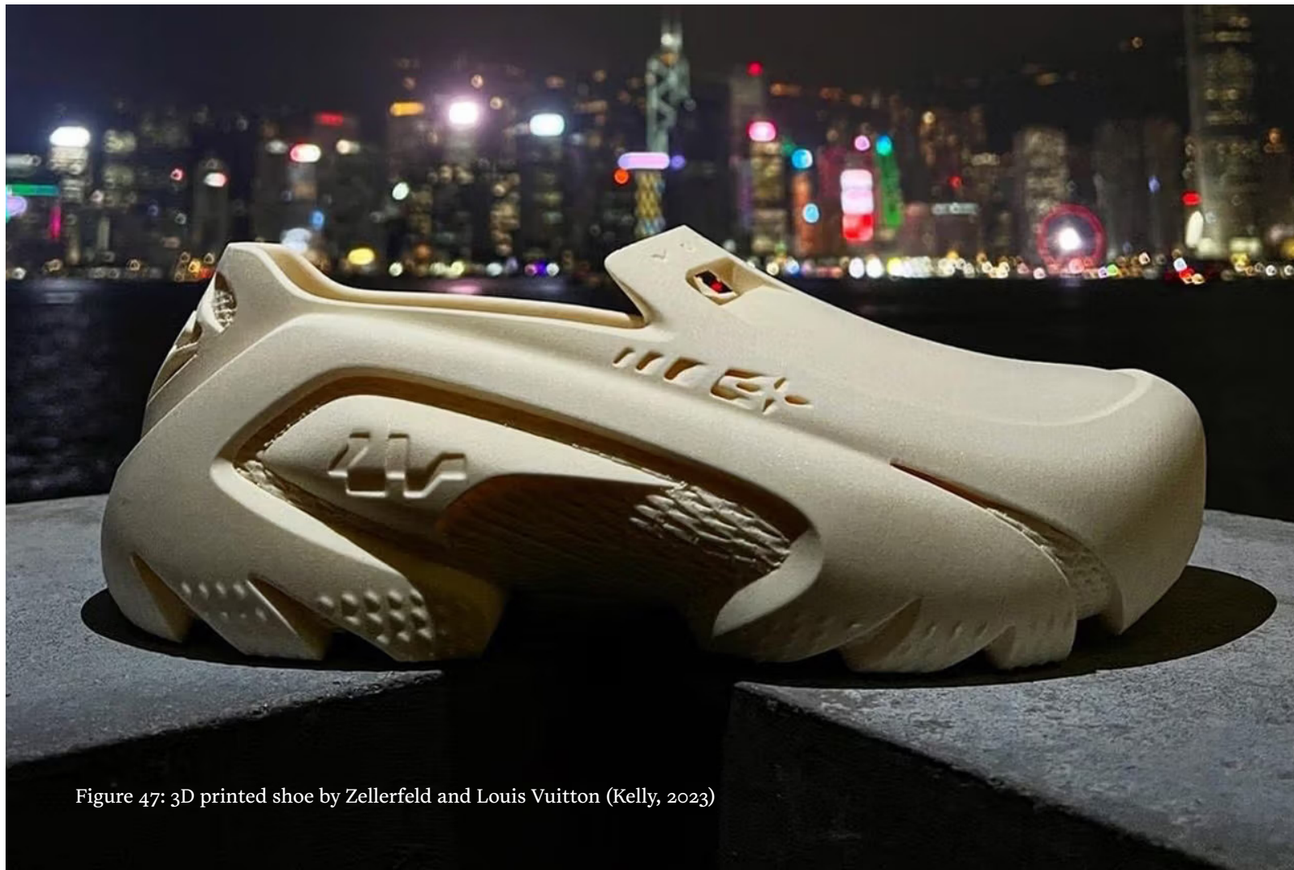


Figure 47: 3D printed shoe by Zellerfeld and Louis Vuitton (Kelly, 2023)

Sustainability Driven: While the empirical research detailed in chapter 3 suggests that sustainability is currently not an important consideration in the selection of children's footwear for most parents, there is a general awareness about the environmental impact associated with the consumption of children's footwear. User testing detailed in chapter 6 and 7 showed enthusiasm about the new system's sustainability benefits compared to existing footwear solutions. Additionally, general environmental awareness and sustainability led consumption is growing with new generations, which are demanding sustainable retail and are willing to spend more on sustainable products (Petro, 2021). However, a wave of greenwashing, and unrealized promises from larger corporations, has also changed some of the sentiment around environmental and social impact claims (Haslam, 2023). LUCA is for those who are looking for brands that are actively taking steps in creating a shift towards better production and consumption, rather than announcing strategies and telling stories.

Gender Neutral & Inclusive: A unique feature of the proposed PSS is the opportunity for parents and children to choose their favorite style of footwear without being limited by the idea that some shoes were made for boys and others are meant for girls. Therefore, the PSS aligns itself with a trend of increasing gender neutrality in young parents, and a focus on raising children with inclusivity in mind (Rahilly, 2022). From personal retail experience, I have seen how existing children's footwear stores are already adjusting their approach to what would have traditionally been sold as boy's or girl's footwear. Store employees are increasingly not supposed to present shoes as either boys' or girls' shoes, as the child is allowed to decide what they like. However, while this might be considered desirable from an inclusivity point of view, this might ultimately be detrimental for healthy foot development with currently available footwear. This is due to common proportional differences between boys' and girls' footwear. Additionally, a company will generally still need to make assumptions about the popularity of certain styles among boys and girls, as this determines the amount of stock that is produced per style and per size. With an on-demand, personalized, 3D printed footwear system, these hurdles can be overcome, as the aesthetics of a shoe can largely be disconnected from the internal physical fit of the shoe.

In addition raising children more gender neutral, the proposed PSS could also help parents who are looking to reconsider their own roles in relation to the consumption of children's footwear. In conversations and interviews with parents, it became clear that in many families, children's shoes are primarily selected and purchased by the mother, possibly in collaboration with the child. This resulted in only one parent being knowledgeable about the child's foot size and preferences. This is aligned with the finding that, even though women are working more, they are still taking on most of the household responsibilities (Germano, 2019). As wider cultural trends are suggesting a redefinition of parental gender roles, the proposed PSS could make it easier for both parents to be engaged in their child's foot development and footwear, as the system makes it easy to track and share foot growth information with each other.

Child Centered and Connection Driven: As detailed in chapter 5, the brand mission is built around the idea of connection and putting the child at the center of the footwear selection process. Therefore, the beachhead market of the proposed PSS is formed by customers that align with these value and believe that it is important to include children in the process of choosing what they wear, and encourage them to develop their own taste and style over time.

Other Brands

Figures 48 to 51 present brands and products in different product categories that could be associated with the beachhead market. This overview provides additional context to the envisioned target segment, and inspiration for further product and brand development.

Figure 48: Artipoppe (Artipoppe, n.d.)

Artipoppe is a modern baby carrier brand born in The Netherlands. It promotes freedom of movement and protection of parent and child, and symbolizes an umcompromised lifestyle.

Figure 49: Naïf (Lunabear, n.d.)

Naïf is a baby care brand based in The Netherlands, that focuses on the creation of care products with ingredients that are both good for the baby's skin and good for the environment.

Figure 50: Bugaboo (Bugaboo, n.d.)

Bugaboo is an innovative stroller brand that specializes in creating selling high quality, luxury strollers in fifty countries, with a mission to design out friction from the daily lives of parents.

Figure 51: Apple Watch (Fabry, 2021)

The Apple Watch has gained popularity through its ability to promote health tracking in a lifestyle friendly way, easy to use and stylish way.

Business Model

The creation of a system that grows with the user and creates an increasingly tailored and personalized product and service experience provides new opportunities for the development of a new type of business model for children's footwear. Rather than repeatedly marketing and selling to the same customer and competing with every other children's footwear brand on the market each time a parent and child are choosing a pair of shoes, the business model should incentivize users to stay inside the LUCA ecosystem for as long as possible. Exploratory customer research in chapter 3.1, and user testing in chatper 7.4, have provided early insights into the potential of a membership and subscription based model for 3D printed children's footwear. A personal fit and footwear account that helps famillies to always have well-fitting and stylish children's footwear at every step was found to be highly desirable. This model would align itself with similar initiatives like On Cyclon, an expanding running footwear subscription service that provides a first proof of concept for the a new type of business model for footwear with a consistent and high replacement rate. As the foot growth of children results in a relatively high and consistent rate of product replacement, this product category could also be uniquely suitable for a subscription based model.

A subscription based system for children's footwear can also be used to further drive the vision of a circular PSS forward. User testing in chapter 7.4 suggests a high level of interest and possible engagement of parents in a take-back system that rewards the return of old footwear, for the purpose of recycling or composting, with discounts or towards future or additional purchases. However, it was also found that a system for personalized 3D printed footwear will likely have a harder time selling pre-owned products that non-personalized counterparts, due to the perceived conflict between the promise of 'personalized' and that of 'pre-owned'. Therefore, a strong focus on efficient and effective recycling or composting systems is required, depending on the material that is used.

Pricing Strategy

As previously stated, the proposed PSS takes on a premium market positioning with a price that reflects this positioning. It is important to understand that such an increased price is not simply a barrier, but rather part of the system's strategy to effectively connect with modern consumers, create a desirable product, and increase the likelihood of customer success. This paragraph outlines the five principles upon this strategy is built.

Zero Midrange: Das et al. (2023) describes the rise of the zero consumer. The zero consumer is one that saves money in some categories and splurges in others, like apparel. This creates an increased demand for both very cheap and luxury brands by one and the same person, and drastically reducing customer demand for mid-range products. Therefore, the proposed system is required to take in a premium positioning if it wants to connect with the target audience and align itself with current consumption trends.

Increasing Social Desirability: The positive health impact on children's foot development is not the only critical success factor of the system. The social desirability and status of this new type of children's footwear is also essential for successful market introduction and fulfilling the mission. Positioning the product as a luxury product, and associating the product with people that parents look up to and trust, can be helpful in creating desirable product associations and diminishing undesirable associations, such as water shoes and Crocs. The choice for a luxury product positioning aligns with the current pricing strategy of Zellerfeld, which offers adult sized fully 3D printed footwear $250 to $370 per pair and collaborates with luxury fashion houses. Such a pricing strategy also takes inspiration from Tesla, which used an initial premium product that successfully changed people's associations with electric vehicles, before driving down prices and moving into a wider market (Musk, 2006).

Scarcity: As speed of production in 3D printed footwear is significantly limited, compared to other methods of footwear production, it will be necessary to be selective about which customers will be accepted in the system, in order to ensure acceptable product delivery times. Even though production capacity is expected to increase significantly with the opening of new factories, industry leader Zellerfeld is currently struggling to fulfill orders, with customers having to wait five months before their order is delivered. This is not acceptable for children's footwear, as a child rapidly outgrows their current footwear. To ensure that every user enrolled in the system can be served in time, access to the system should be limited and carefully increased. This inherent production limit and scarcity of the product could further be used to increase value perceptions and increase urgency for people to join and stay in the system when they still can, as they might not have access later.

Increasing Investment: Premium pricing can also be an effective tool to increase customers' investment and their likelihood of achievement of desirable results. "Those who pay the most, pay the most attention" (Hormozi, 2021). The proposed PSS could greatly benefit from this, as consistent product and service use is required for an increasingly personalized experience and desirable foot health results over time.

A Five Star Experience: Starting from the luxury segment would provide with more headroom to create a system that delivers on its promise and provides a five-star experience that I would be proud to offer to people. Greater revenue is essential to be able to invest in greater efficieny, an exceptional customer, pampering clients, scaling the business and hiring the best people. Furthermore, setting a higher price and focusing on customer with sufficient purchasing power can provide another benefit: the customers are easier to satisfy. While raising prices can effectively increase the value perception and allure tied to the product or service, decreasing prices is likely to attract 'bad' clients who are never truly satisfied until the product or service is free. Therefore, if the system is able to deliver on its promise, high paying customers are considered easier to satisfy and will actually cost less to fulfill (Hormozi, 2021).

Foot Health vs a Cup of Coffee

Gradual expension towards a greater amount of customers could require a pricing strategy that makes the premium price of the proposed product-service system more accessible. Based on exploratory research, it could be assumed that, while the average willingness to pay per pair of shoes goes down for younger children, the overall expenses related to footwear consumption over time stay stable. This means that in early ages, parents will likely spend less per shoe, but the same amount per year. Based on available data on the replacement rate of footwear through various age groups until twelve years old, a calculation can be made that reveals a new pricing strategy that could make personalized, 3D printed footwear more accessible to a greater audience.

Until the age of three, an average replacement rate for children's footwear was estimated at three to four pairs of shoes. This number decreases to between two and three pairs of shoes between the ages of four and eight, and one to two pairs between the ages of nine and twelve (How often do you need to replace your child's shoes?, 2017). For further price calculation, the higher number of pairs is used for each age group. If we would consider an annual subscription price for LUCA at €500, this would bring the cost of a pair of shoes for children between the ages of nine and twelve to €250, while the cost per pair goes down to €167 and €125 for the age groups of four to eight and zero to three respectively. As the price of manufacturing 3D printed footwear is highly dependent on the volume of the product, and current providers of 3D printed footwear are able to deliver products in adult sizes at a retail price of €250, this pricing is considered realistic. Further breaking down the cost of the subscription over different periods of time reveals how such a pricing strategy makes the system more accessible to more users. Spreading the annual subscription of €500 over multiple payments allows this price to be translated into approximately €40/month or €1,37/day. This brings the cost of 'healthy foot growth in style for your child' to a cost that is lower than your daily cup of coffee.

8.2 Key Activities & Strategic Partnerships

This chapter details the key activities that are required for creating the proposed circular product-service system for children's footwear. Additionally, a core team and set of desirable strategic partners was defined in order to fulfill the identified key activities.

Design & Development

One of the key activities for realizing the proposed product-service system is the design and development of desirable footwear styles that suit the target group. Two industry developments are currently completely transforming the way in which new footwear styles are created: artificial intelligence and crowdsourcing. AI has made it possible to create hundreds of designs and variations within minutes, using a simple text prompt or visual reference. Additionally, an extensive online community of 3D footwear designers has grown and connected with each others in recent years. Rather than having a dedicated internal footwear design department, the design of footwear is being democratized and led by individual 3D footwear designers. Of each product sold, Zellerfeld shares the profit with the individual designer, creating a structure that is mutually beneficial and allows for rapid creation of new styles.

However, the availability of too many style options was identified as a potential hurdle for the target group of this project, as choice paralysis of parent and child is likely to occur. Therefore, while aspects of the design and development of new styles can be outsourced and done in collaboration with freelance designers, the company requires a core team that is very intentional about the design and curation of a high quality collection that provides sufficient choice of styles, covering a large variety of footwear categories, acitivities and occasions. Depending on the method of printing, prototypes can increasingly be created from desktop printers, which allows for rapid in-house prototyping, iteration and feedback. In addition, partnership with foot health and footwear experts is likely necessary to substantiate possible health claims about the system and earn the trust of parents to invest in a system and product that is going on their child's feet.

Measurement & Style Selection

A second key activity for the realization of the proposed PSS is the foot measurement and style selection process in a physical store context. The collection and processing of foot data is essential to creating footwear with an accurately personalized fit. Capturing this data requires scanning equipment that can both capture static and dynamic foot data, providing a complete picture of the user's feet. Additionally, creating a personalized fit requires algorithms that can accurately translate this data into a well-fitting shoe. Based on previous informal conversations and collaboration with industry experts, it can be concluded that it is already possible to develop algorithms that accurately generate personalized shoe lasts based on relatively simple foot scans. This does, however, require a great level of expertise in computational design and programming software. It could, therefore, be wise to explore partnerships with existing fit tech companies like Volumental and Safesize. These companies offer in-store and mobile scanning solutions, and have generated a database of millions of foot scans that provide a strong base to create an accurate personal fit. Current limitations around the collection of foot data should be addressed in collaboration with partners to eventually also include dynamic foot data, rather than static data. In order to fully understand the user's footwear needs and to provide a correct fit, the foot should preferrably be measured in movement, as this is also the condition under which footwear is supposed to function. Inspiration for such scanning systems can be found in previous research from Kwa (2021), which details the development of a low cost, 4D foot scanner for podiatrists.

An important strategic consideration, however, is that the generation and collection of personal foot data is of high value to LUCA, as capturing detailed data about a child's foot development allows the company be closer to the customer

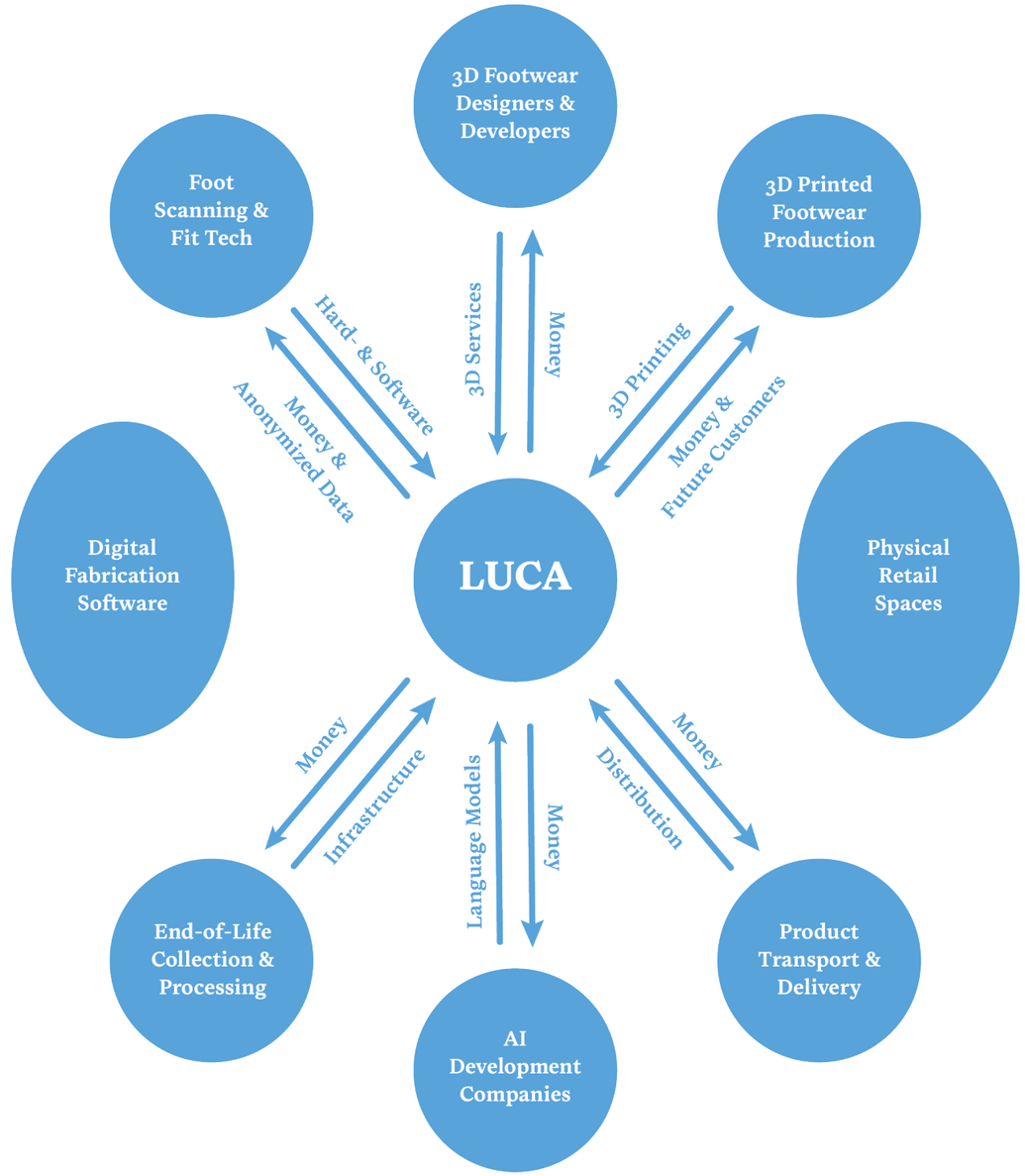


Figure 52: Overview of partners and suppliers

than any other footwear provider and grow with the customer. This is true during use of the system, but also when children grow up and they might want to use the generated personal fit data to seemlessly transition into adult footwear. Additionally, over time, the collected foot development data could lead to potential new insights into foot development and the impact of footwear. Therefore, the collection of personal fit data is a key strategic element, and ownership of this data is of great importance for the company and should be carefully considered in any kind of collaborative structure. Additionally, it is important to provide data security and privacy for users of the system. Therefore, handling of personal scanning data of users should either be done in-house or in very close collaboration with trustworthy partners.

Finally, it was identified through user research, detailed in chapter 7.4, that human retail assistance will be required for providing additional help at the physical point of retail and to attract customers to engage with the experience, as it will be largely unknown to the target group at initial launch. As described in chapter 7.1, LUCA could benefit from collaboration with other complementary brands for the creation of a shared retail location, driving down initial costs, while potentially increasing traction and creating a more complete experience. Existing luxury department stores might also offer opportunities for the creation of shop-in-shop locations.

Sourcing & Manufacturing

The production of 3D printed footwear is radically different from the production of traditional footwear, in terms of materials, manufacturing and assembly. This provides new challenges and great opportunities to simplify the entire supply chain that is needed to bring personalized footwear to the user. For this project, the proposed method of 3D printing is Fused Deposition Modeling (FDM), which is based on adding material layer-by-layer until a shoe is created, consisting of one part. Several on-demand 3D printing companies are currently starting to expand their acitivities in footwear production. Due to high investment costs and highly specialized skills needed to build, operate and buy printers, and deliver products of sufficient quality, it is advised that production is done in collaboration with manufacturing partners. Sourcing and development of materials should also be done in direct collaboration with manufacturing facilities, as the possibilities for material innovation are heavily connected to the machines that are used.

Product Distribution

Product distribution is another key activity in the realization of the new system for on-demand, 3D printed children's footwear. As products are delivered to the customer, partnerships should be initiated with international and local delivery services. Additional thought should be given to the process of product quality control, as the place where this happens determines the logistics necessary in order to get the product to the user. If this step is done by the manufacturer, this would require one less step in the product fulfillment process, compared to if this step when to be done in a seperate facility.

Product Use & Maintenance

When operations are running, partnerships with web development and AI companies would be necessary to deliver a personal experience and let Luca grow with its users. Available API's, like those from OpenAI, could be used for the creation of highly capable online chatbots that are able to accurately answer any questions around product use and maintenance. Other activities should be focused on helping potential users to overcome any hurdles to using the Luca ecosystem successfully. Other aspects of the service, such as fit check reminders and the mobile foot scanning process, are automated.

End-of-Life

The creation of a circular system for personalized, 3D printed children's footwear also requires key activities around the end-of-life product phase. A collection system is needed to efficiently bring the used product from the user to the correct facilities. In the early stages of the company, a direct collection system could be used that gets used shoes from the user back to the company. Through user testing, detailed in chapter 7.4, it was found that potential users of the system would prefer the possibility to return used shoes at the physical point of retail, instead of solutions that require return shipments. A second opportunity for collection of used product exists in the collaboration with existing footwear collection organizations. Organizations like Sympany have a wide network of collection bins and facilities, and work closely together with municipalities to scale up end-of-use footwear collection and sorting. As production scales and more users are added to the system, the wide availability of such collection bins could make it more convenient and efficient to collect and process used shoes, for both the brand and the user.

In addition to the environmental benefit, the collection of used products allows the brand to inspect wear and tear patterns at end-of-life. This could provide the brand with important product information and, in combination with the flexibility of production, enables rapid product improvement and iteration. Furthermore, wear patterns can also provide valuable insights into a child's strike pattern, generate more data to better capture the child's foot growth over time, and create products with a greater level of personalization. Such end-of-use product analysis could be done manually initially, in order to get early product performance insights. Once production is starting to scale, this process should be automated. For every pair of 3D printed shoes, a digital twin will exist. Used shoes can then be compared automatically to this digital representation of the product. As described in chapter 4, Early proof of concept of such systems is already provided by Nike in the shape of B.I.L.L., their footwear cleaning robot, and Zellerfeld and the University of Bremen, who investigated the use of deep learning models to compare printed shoes to digital models for automatic quality control (Nike, 2022; Kreutz et al., 2022).

With regards to the processing of used shoes, a decision should be made about the material that is used. Choosing for petroleum based TPU would mean a focus on the recycling of used products. This would provide the following two options: open loop or closed loop recycling. Closed loop would mean that shoes are recycled into new material resources that can be used to print new footwear. This approach does have limitations related to the recirculation of materials, as the materials currently undergo processes that change the material characteristics, resulting in a product that is genearally less flexible. Therefore, new products will mostly consist of added virgin material. For this reason, an open loop and collaboration based approach to recycling, as proposed by Kate Raworth might be desirable long-term (Renegade Inc., 2017). Since materials are no longer restricted to being used in the same product, in such an open loop system, the decreased flexibility that results from material recycling can be used as an asset in the creation of other types of products that require different material characteristics. Choosing for compostable biopolymers, on the other hand, would require a focus on composting processes for footwear that can no longer be worn. In order to make a choice between petroleum based, recyclable filament and biobased, compostable filament, futher experimentation will be necessary to fully understand the product performance aspects, such as durability, support and comfort. This experimentation and material research should be key development activities going forward.

Figure 52 provides an overview of the described partnerships. Figure 53 provides a visual overview of the key activities inside the proposed PSS.

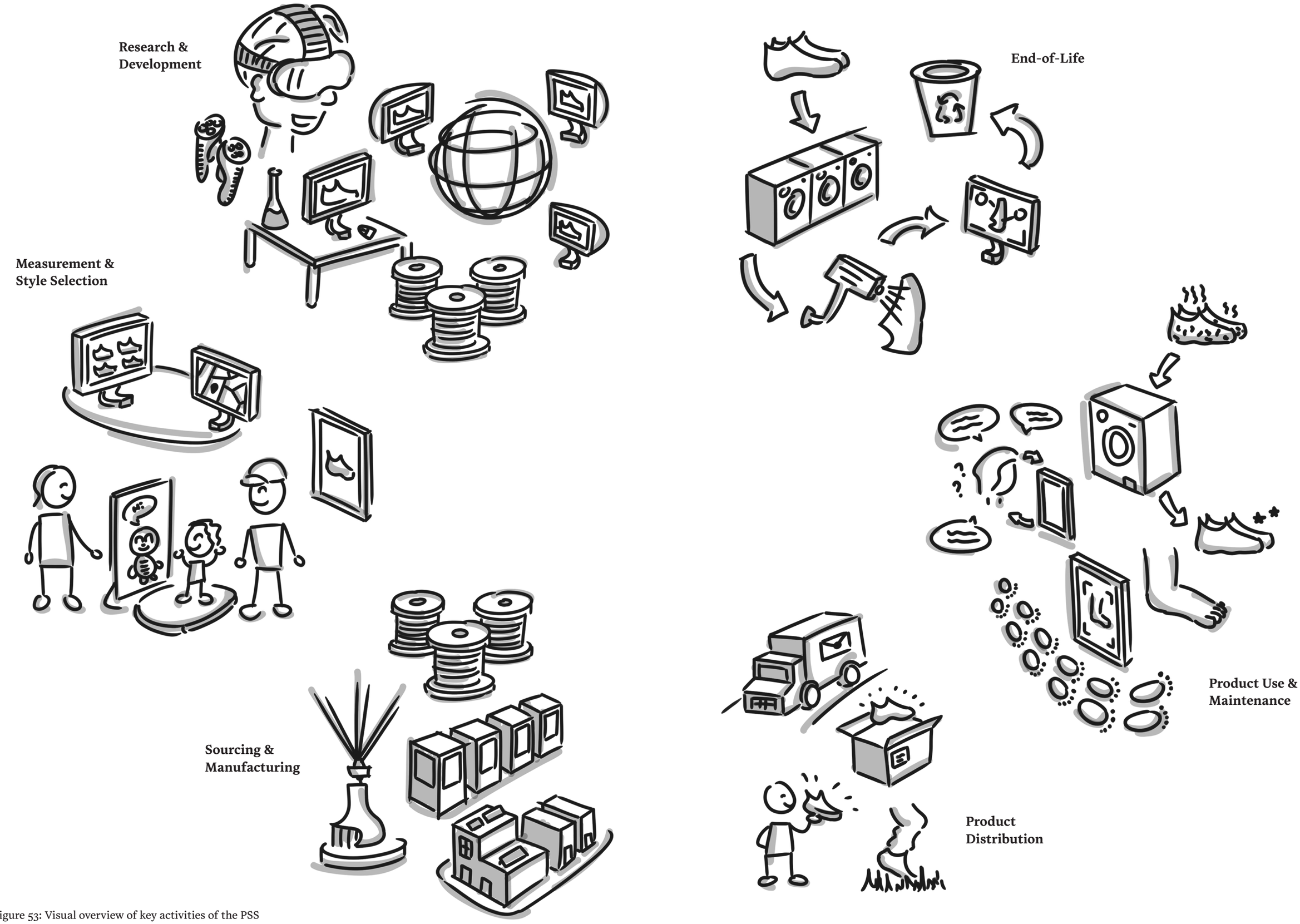


Figure 53: Visual overview of key activities of the PSS

Marketing

A final key activity that is required to keep the PSS running is marketing. Traditionally, marketing spend has been a significant part of the cost structure for footwear and apparel companies, as much of product adoption and selection is dependend on brand affinity. Personal conversations with industry professionals have led me to understand that many footwear trends are born inside of the boardrooms of major industry players and demand for certain styles is created over time through costly marketing efforts and collaboration with influencers. While more recent startup apparel brands like Gymshark and Filling Pieces have been successful in creating a valuable brand in the footwear and apparel space through organic online growth, adoption of these platforms by big industry players has also made this a highly competitive space. Leaders in the digital marketing space like Gary Vaynerchuck have repeatedly stressed the fact that brands need to post at least a hundred pieces of content every day, in order to create enough brand exposure and reach customers in this stage of social media marketing (teamgaryvee, 2019). Therefore, a key activity includes the rapid creation of various types of digital content through platforms like Facebook, Instagram, Snapchat, TikTok and Youtube.

In addition to direct competition and increasing digital marketing costs, increased regulation on user data collection and commercial use through social media has left brands needing to cast a wider net in order to reach the desired customer (Binkley, 2021). Furthermore, additional restrictions are implemented by Meta, which continue to restrict targeted adverstising to minors (Sato, 2023). For a children's product, it is important to consider that the official minimum age of apps like TikTok is thirteen years old. Therefore, digital advertising efforts are best focused on parents. Previous chapters have also stressed the important role that social media plays in educating parents about the impact of footwear on foot health, and the starting point that it forms for the consumption of footwear in modern parents.

In addition to digital advertising, physical advertising can play an important role in launch of the system. As the PSS is reliant of physical points of retail, marketing efforts will largely be focused on creating local traffic towards the shopping stations and driving a local community of LUCA users. As shown in figure 54, physical advertising might be used to speak to both parents and children, by bringing parents' attention to their child's feet, and by sparking children's curiosity through the image of Luca.

Figure 54: Mockup of physical advertisement for LUCA

8.3 Implementation Timeline

This chapter presents an overview of the key milestones and activities that are needed for further development and reaching market launch of the proposed product-service system. Additionally, this chapter details the cost structure, metrics, legal and ethical considerations and critical success factors for the realization of the proposed system for 3D printed children's footwear.

Introduction

An overview of the implementation timeline for the proposed PSS is visualized in figure 55 . This timeline divides the process of future system development into six phases, from creating an audience to the launch of an open beta program. For each phase, the key activities, costs, metrics and channels are considered. Finally, an overview of legal and ethical considerations, risks and critical success factors is provided. The goal of this chapter is to translate the long-term vision of the system into tangible, short-term steps, creating a map for execution and market implementation.

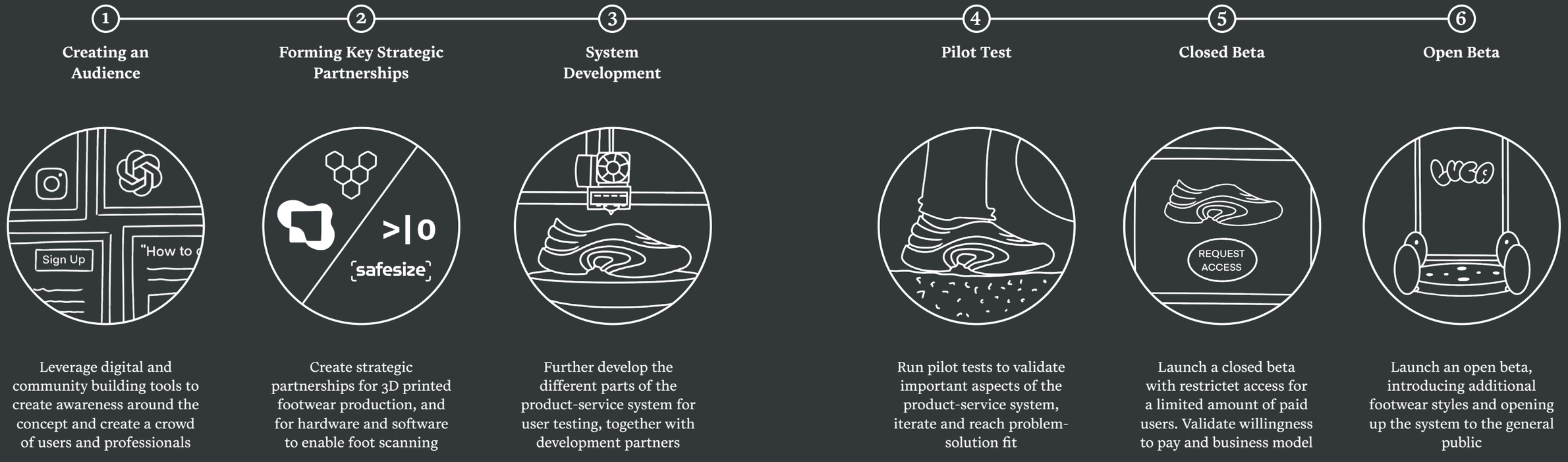
Creating an Audience

The first phase of the implementation timeline is concerned with creating an initial audience. In order to further determine the desirability of the proposed system, the project results should be communicated to and engage both potential users and industry professionals. The key activities of this phase involve the creation of social media channels and an online product landing page were the project is communicated to the public. By publishing about the project and engaging with potential users and professionals, the concept can further be refined. Additionally, it allows for early market validation through email sign-ups on the landing page, and the creation of a social media community that is directly engaged and involved with the project's development. This core group of potential users could also serve as an initial target audience and/or brand ambassadors for future product launch. Further publicity through established design outlets is desirable to increase the digital reach of the project and get industry professionals involved. This could also be achieved through the attendance of relevant conferences and presentations around footwear innovation and additive manufacturing. In addition to sharing direct project outcomes, articles about children's foot health, 3D printed footwear and related topics could be published on a blog, supporting further research and sharing of information on these topics, and potentially creating a good source of information for parents and children to access information around footwear and foot health. Furthermore, the creation of such a blog could serve an important role for increasing online findability, and the digital presence of LUCA pre- and post-product launch. Finally, the implementation of GPT's by OpenAI on the website of LUCA allows for the creation of a chatbot that answers questions from parents and children with regards to footwear and foot health. Written blog articles and interviews with industry and health professionals could further serve as additional source of information for such a chatbot to be based on, to ensure high quality and accurate information.

Forming Key Strategic Partnerships

Due to the relative complexity of the system and early stage that 3D printing and scanning for footwear are currently in, the next phase of this project would involve the creation of key strategic partnerships for production and foot scanning. Based on current brands and partnerships in the space of 3D printed footwear, four companies could be considered. First of all, a direct partnership with fit tech companies such as Volumental or Safesize would be essential for the creation of a system that is able to accurately capture foot data and generate fit data that can be used to create products with a personalized physical fit. Volumental is already involved in at least two projects around 3D printed footwear, through both its physical scanning platforms and mobile foot scanning application.

Figure 55: Implementation timeline for LUCA



Secondly, the creation of the proposed PSS requires partnership with a company that can deliver high quality, 3D printed footwear. As leading 3D printed footwear manufacturer, Zellerfeld is currently uniquely positioned to support such a project, due to its existing and expanding infrastructure, production capacity and product quality. Additionally, Vivobarefoot could be considered, as they are currently launching their 3D printed footwear service in collaboration with compostable filament manufacturer Balena. Vivobarefoot has announced plans to open 3D printing facilities in the UK, Germany and the US. It should also be mentioned that partnership with Vivobarefoot would likely facilitate the production of barefoot styles only. Zellerfeld, on the other hand, currently makes use of two shoe last styles, a 'traditional' and a 'sneaker' last, and there are currently no options for the creation of barefoot styles. The creation of children's footwear, however, would require the development of new lasts and grading/scaling systems that allow the 3D model to be adjusted to the correct size, based on an individual's fit data. Finally, both Zellerfeld and Vivobarefoot have already established partnerships with fit tech company Volumental, which makes Volumental a likely partner for capturing foot data.

System Development

Together with the mentioned partners, the system and its parts can be further developed. This involves the creation of shoe lasts, a grading system, footwear styles for children, and the production of wearable prototypes. Based on the findings in this thesis, the need for additions to create a year-round product should also be considered (see chapter 6). Furthermore, the store experience has to be developed. This would involve the creation of in-store on-screen interactions with the Luca character and implementation of the scanning platform. Furthermore, the AR powered in-store virtual try-on system should be finalized, potentially partnering with Snap AR. Finally, the mobile service should be developed. This involves the creation of user profiles, integration of mobile scanning, potentially the addition of mobile virtual try-on options, and a system that can send messages reminding users of to check the child's footwear fit consistently.

Pilot Test

An unpaid pilot should be used for early market validation. Together with a selection of community members, the wearable footwear prototypes should be tested for a few months to validate product performance in real world scenarios, and the desirability and performance of the store and mobile experience should be determined. The data from this pilot can be used to understand if a problem-solution fit is achieved and what aspects of the design need to be changed (Coelen, 2021).

Launch

Closed Beta

After the completion of a successful unpaid pilot, a business model and pricing strategy should be defined and tested. By launch of a paid pilot in the form of a closed beta, the willingness to pay for the developed PSS can be determined. This paid pilot is restricted in the amount of users that can be onboarded. The viability of the business model should be determined with paid users. This involves understanding unit economics, such as the Customer Acquisition Cost, and metrics such as Customer Retention to understand if people are willing to pay and keep using the system. A closed beta would involve the opening of a first store in a specific geographic location that allows users to engage with the system in the intended way.

In order to drive traction during this closed beta, different channels could be used for marketing purposes. In addition to the brand's own digital communication channels, this could involve collaboration with 'momfluencers', mothers who have monetized their maternal identity on social media, or designers to create communications and products that resonate with the target audience of new mothers (North, 2023). The physical store that is used during the closed beta can simultaneously act as an offline marketing tool. It could be important to, therefore, have the store located in high traffic areas in the city center. As the amount of users during this paid pilot should be limited and grown locally, referral strategies like the one implemented by phone manufacturer Oneplus could be considered. During the launchy of their first mobile phone, each customer received two tickets that could be forwarded to other people, which would allow those people access to the product. Overall the use of the closed beta is not only to test customer's willingness to pay for the system, but it also serves as a way to create increased demand and desirability through the exclusivity of the initial limited release. The closed beta of Zellerfeld, for instance, required users to sign up and get selected, after which they were able to choose from a couple of footwear styles, designed by different well-known designers. The closed beta launch of LUCA should also be done with a very limited amount of style options.

As fully 3D printed footwear is currently limited in its capability to protect the users from cold weather conditions, the time of the year should be carefully considered. Alternatively, it might be worth considering placing the first store(s) in countries or regions around the world that provide mostly warm and dry weather conditions throughout the year.

Customer reviews should be used to determine customer satisfaction and further steps for improvement of the system. The estimated time for this phase is around six months.

Open Beta

After completion of a successful closed beta, the open beta can be launched. In this phase, the store will officially be opened to the general public, and a couple of additional physical retail locations should be opened. As the system relies on physical store locations, offline advertising and a strong focus on creating local communities of users are needed to gain traction. Additionally, this phase would be paired with the introduction of additional footwear styles that users can choose from. Collaboration with popular children's brands and franchises should be considered to increase demand under children. Customer reviews, and metrics such as customer retention rate, customer acquisition cost and life time value should further be used to assess the desirability, viability and scalability of the system.

Legal and Ethical Considerations

Data Privacy

Implementation of the PSS should consider how user data is collected, processed and stored, and focus on the creation of processes that promote data security.

Patents

Implementation of the PSS should consider existing and upcoming patents around 3D printing and scanning related to footwear.

Risks & Critical Success Factors

Reliance of physical retail locations

The current system design is highly reliant on physical points of retail. This brings risks, as it requires strategic geographical targeting. Moreover, users would not be able to stay in the system if they move to a different location, or if a store closes.

Reliance on Partners

The proposed PSS is highly reliant on the success of strategic partnerships for the purpose of production and data collection.

Speed of Production

Realization of the proposed PSS is very much dependent on speed of production of 3D printed footwear reaching a certain threshold.

Creating A Year-Round Product

A system that grows with the user requires the development of a product and a geographical market that ensure year-round usability. Additionally, the trend sensitivity of footwear might offer additional challenges for retaining success over time.

End-of-Life

Creating a circular PSS for personalized children's footwear requires material innovation, infrastructure and partnerships to ensure correct collection and processing of products at end-of-life.

09

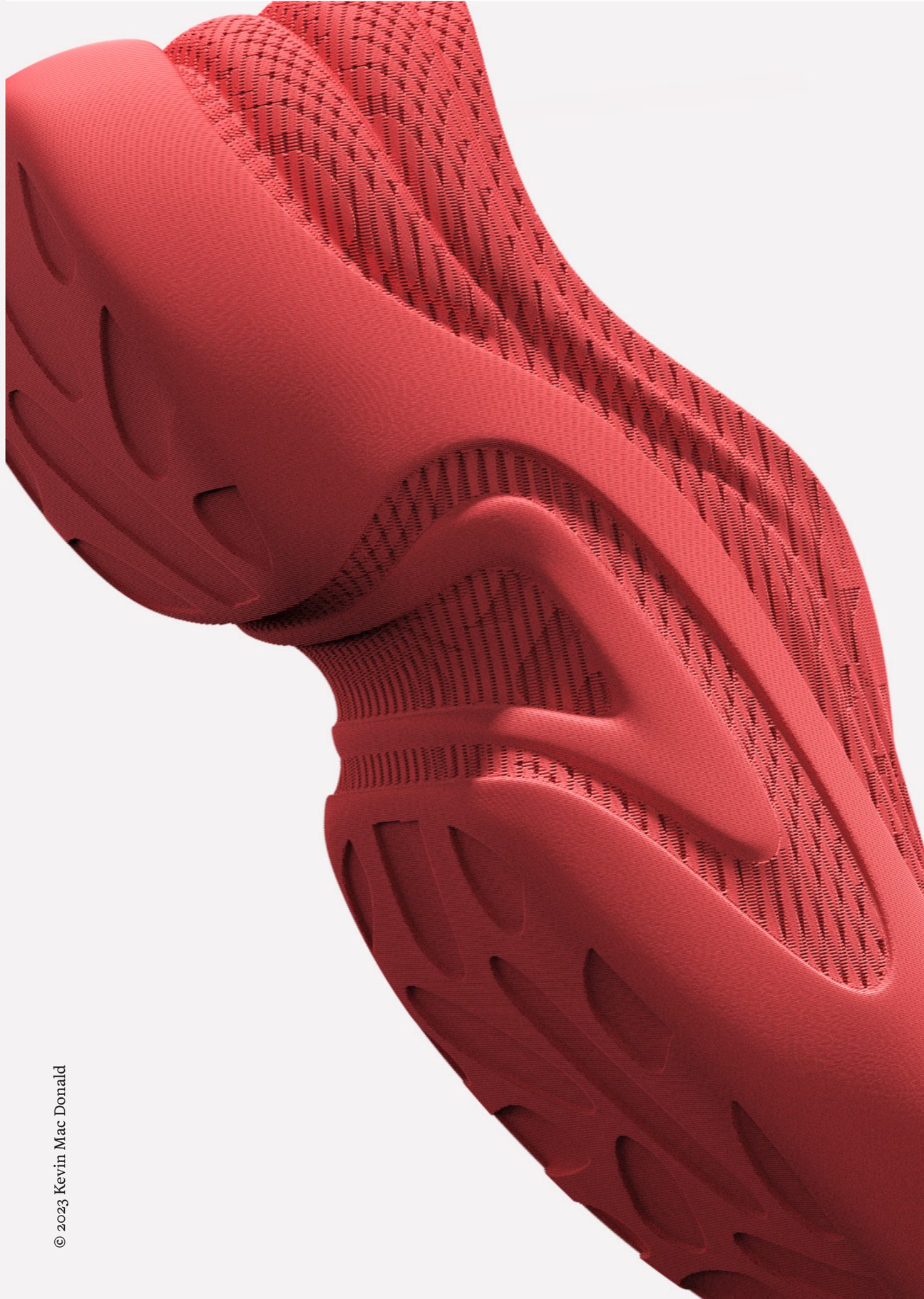
Conclusion of The Project

This chapter describes the final discussion, conclusion and personal reflection of the project. The discussion provides a summary of the design outcomes, and reflects on key findings of this thesis. Additionally, project limitations and recommendations for future research are detailed. The conclusion provides an overview of the main project insights, resulting from the exploratory research, and the design and user testing activities. Furthermore, it reflects on the place and contributions of the project within an academic and industry context. The final section contains a personal reflection on the graduation project, detailing the journey, personal insights, personal learning ambitions set prior to the start of the project, and future ambitions.

9.1 Discussion

9.2 Conclusion

9.3 Personal Reflection



9.1 Discussion

Summary of Key Findings

Children and their parents are considering both the aesthetic or symbolic value, and the functional value of the product when choosing a pair of children's shoes. Therefore, finding the correct fit is composed of a physical fit aspect, as well as an identity fit and social fit part. Current footwear solutions require the user to make a compromise between these forms of fit, as the appearance of a product is directly tied to a specific set of inside dimensions and fit. Such compromises can negatively affect foot development and lifelong mobility of the child, as well as their personal identity and psychosocial development. This thesis argues that a shift towards online shopping has further put the child out of the footwear selection process, as parents are looking for convenience and variety of options, possibly leading to further challenges with regards to providing children with well-fitting footwear. Furthermore, many children are wearing shoes that are too small for too long, as a result of a lack of awareness and communication between children and parents around fit checking between store visits. Therefore, this thesis investigated how a product-service system for children's footwear could be developed that removes the need to compromise between the appearance and physical fit of the shoes, promotes involvement of the child in the footwear selection process, and encourages more pro-active replacement and consumption behavior of children's footwear. Furthermore, this thesis investigated applications and new business models for 3D printing in footwear, as well as circular design opportunities, to create a proposal for such a new PSS.

This thesis argues and demonstrates with a combination of digital and physical concept designs and prototypes, and user testing, the opportunity to create a system that effectively removes certain barriers to finding an optimal fit, engages the child in the footwear selection process, and promotes more pro-active replacement and consumption behavior of children's footwear. Furthermore, this thesis argues the opportunity for a membership based approach to 3D printed children's footwear, and a system that grows along with its users over time. Finally, this thesis demonstrates opportunities for the creation of a system that promotes the shift towards a circular footwear industry through waste reduction through on-demand production, take-back systems, and recycling or composting practices at end-of-life.

Reflection on Process & Outcomes

By engaging in in-depth and extensive secondary research in the fields of footwear, foot health, consumer behavior, 3D printing and sustainability, a strong theoretical foundation for this thesis was created. Furthermore, engaging in exploratory research with parents as end-users, and key decision-makers of the designed system, allowed for a design process that was based on direct user insights and repeated engagement with users throughout the design process. Furthermore, this information was combined with previous experience in the field of retail for children's footwear. Personal and professional experience in the field of footwear design, manufacturing, circular design and marketing have further informed the direction that this project has taken and the design decisions that were made. Through the creation of high fidelity physical and digital prototypes, key aspects of the proposed PSS were explored and tested with parents as end-users of the envisioned system. This has confirmed and challenges certain choices for the initial design and provided numerous insights for further development of the proposed PSS, and good basis for further design and business exploration.

Validity, Reliability and Generalisability

This thesis argues that the decision to select parents of children up to twelve years old for the empirical research is appropriate. This because of the important role they play in the footwear selection process of their children, and the role they play in shaping the consumer behavior of their children. Furthermore, it allowed for direct engagement with end-users of the design, within the limitations and constraints of this thesis. This research has provided new insights and perspectives that add to the existing literature in a meaningful way, and enriched my personal understanding of the desires, challenges and dynamics at play in the context of childrens' footwear. Additionally, the appropriateness of the design tools and methods used in this project is supported by the nuanced feedback that was received during user testing, which included both positive and negative assessments of different aspects of the proposed PSS, by both parents that were involved from the start of this project, and parents that were only involved during final user testing.

Regarding the reliability of this research, research and design materials have all been shared with the supervisors of this graduation project. Furthermore, replicability and consistency of the project is maintained by keeping detailed records of the activities, decisions and thought processes throughout this thesis. Qualitative research involved complete audio-recordings, transcripts and written notes. Non recorded interactions and pilot interviews that were part of this thesis have all been treated as informal conversations.

With regards to generalisability of the insights of this thesis, it is suggested that the desires, challenges and dynamics at play in the consumption of children's footwear, are generalisable to other families. This is mostly within a national context, as most participants involved in this study lived in the Netherlands at the time of the study or had previously lived in the Netherlands. However, engagement with parents living outside of the Netherlands has also created initial insights that might indicate differences in perspectives between different nationalities and cultures. Furthermore, the insights of this thesis are influenced by sample selection and require future research to confirm broader application.

Limitations

A main limitation of this thesis is the lack of direct engagement with children as end-users. Due to time constraints, this thesis has limited itself to engaging with parents for the inital design proposal for a new PSS. Therefore, the desirability of the proposed PSS is tested with parents within this project. However, the child's perspective is equally important to determine the desirability of the system, and would largely influence the parents' perception of the concept.

Furthermore, concept testing in this thesis has relied on visual and digital representations of the concept, and were presented through online conversations with participants. The project mainly focused on initial perceptions and associations of participants, based on the provided visual content. While this does provide insights into the uncertainties and perceived risks with that should be addressed for development of the concept, it does not provide direct validation of the product characteristics, nor does it provide direct information about to which degree the desired future interactions will actually result from the design.

Another limitation of this project is the limited sample size and the sampling methods that were used to find participants. It is probable that not all perspectives are included or respresented by the participants that were involved. Therefore, further user research and market validation is required to get a more complete understanding of the generalisability of the findings of this thesis.

A final limitation in this project is based on the amount of 3D printed footwear styles that were part of this project. As 3D printing allows for the creation of a wide variety of radically different designs, the initial collection that was designed within this thesis has only provided a limited idea and representation of what is possible with regards to aesthetic value of 3D printed children's footwear.

Recommendations for Future Research

Based on the identified limitations of this thesis' results, and the insights gained through user testing of the proposed concept, several oppertunities for future research are recommended.

First of all, future research and development requires direct engagement with children as end-users of the proposed PSS. During this thesis, various prototypes were developed that could provide direct insights into the interaction and perception of children with the different parts of the system. Due to time constraints and ethics considerations, these were not used within the context of this study yet. However, a next step would be to use the prototypes that were created and further iterate on each of the system's parts based on these test results.

Second, future research and development of the system requires direct user testing of the store and service experience that was designed in this thesis. This would provide insights that go further than the perceived desirability and associations that this project addressed. Additionally, it would be valuable to test to what degree the proposed mobile service is capable of inspiring and facilitating more pro-active footwear replacement and consumption behavior with users of the system. This might also involve assessment of foot growth prediction tools, as this study suggests the possible importance of this feature to achieve the desired user behavior.

Third, future development of 3D printed footwear for children should consider the perceived product limitations as identified in this thesis. Most importantly, this concerns possible solutions for increased wearability in cold weather, optimal ease of use, and ways to accomodate gradual foot growth and maintain a good physical fit to extend usability and reduce the need for product replacement.

Fourth, this thesis suggests that there could be a significant opportunity in the field of orthopedic footwear for children. This direction was not further explored in this project as it was out of scope, and requires in-depth user research and expert involvement in this specific area of children's footwear. Future research could determine if there are opportunities for the implementation of a system, such as the one proposed in this thesis, in this field.
Fifth, future research should consider further development of 4D foot scanning technologies for the creation of more detailed data to inform the fit of the product, and generate a more detailed image of the users foot development over time.

Sixth, future research should explore the end-of-life opportunities for fully 3D printed footwear. Most importantly, this concerns assessment and development of closed and open loop recycling possibilities for TPU, as well as opportunities for composting of biopolymers used in 3D printed footwear. Additionally, the impact of microplastics resulting from 3D printed shoes should be addressed, in use and through machine washing.

Seventh, future research should address data practices and regulations around foot and fit data, especially with regards to data from children.

Eighth, as this project mainly builds on the opportunities of FDM, future research could address possibilities for the production of children's footwear using SLA or Powder Bed Fusion as 3D printing methods.

And finally, future research and development of the system should validate end-users' willingness to pay for the proposed PSS, as well as the opportunity to use subscripton models, and the ability of the system to keep users in the system between the first shoes and the time the child becomes twelve.

9.2 Conclusion

This thesis explores and investigates how the design of a new product-service system for 3D printed children's footwear can help children under thirteen years old, and their parents as key-decision makers in the selection process, to buy the footwear they want, without compromising on the child's foot health and lifelong mobility. Additionally, this thesis explores circular business models and new target segments for 3D printed footwear. Based on qualitative data obtained from empirical design research - in the form of semi-structured interviews with parents of children under thirteen years old as end-users and key decision-makers in the proposed PSS - it can be concluded that a new system for children's footwear should help to remove current barriers to finding optimally fitting footwear. Hereby, an optimal fit considers the physical fit of the product, as well as the identity and social fit. Furthermore, the system has to put the child at the center of the foot measurement and style selection process, and more pro-active replacement and consumption of children's footwear should be inspired and facilitated for healthier foot development. The results of this thesis indicate the need for a PSS that consists of three key elements: an in-store experience, a mobile service, and a physical product.

By exploring current products and user interactions with existing solutions for children's footwear, this thesis found that foot health and development is considered a highly important factor for parents in the selection of children's footwear. However, it was also found that parents can experience challenges with regards to determining what constitutes an appropriate physical fit in footwear for their child. Moreover, consumption behavior around children's footwear has shifted to mostly online consumption, following parents' desire to have plenty of style and color options to choose from. This thesis suggests that the developed in-store concept as part of the proposed PSS is considered desirable by most parents. Furthermore, the experience is expected to be engaging for children, and expected to result in a product with an optimal physical fit and a desirable aesthetic. Based on parents' willingness to engage with the in-store experience, and positive expectations around the child's perspective on this part of the system, this thesis argues that the proposed concept - consisting of a foot measurement procedure and an AR mirror procedure for style selection - can be successful at bringing the child back into the footwear selection process, where it was increasingly removed due to a shift to online shopping. Furthermore, the in-store experience should be combined with a digital store for pre-selection of styles, in order to provide an omnichannel customer experience that is able to provide the desired convenience, and is able to support the changing dynamics of co-consumption between parent and child in the consumption of children's footwear. However, future development should also consider how physical fit information is communicated to users as a tool to guide further footwear consumption.

This thesis also argues the need for a mobile service as part of the proposed PSS, as it suggests its user for inspiring and facilitating more pro-active footwear replacement habits. This can be achieved through a combination of reminders and mobile foot scanning services that creates increased awareness about regular fit checking, removes communication barriers, and provides a way to easily determine the correct moment for a child to switch to another size.

In order to explore the current application of 3D printing to children's footwear, a collection of five different shoe models was created. This thesis suggests that the aesthetic that can be created with fully 3D printed footwear is generally considered acceptable and suitable for children, by their parents. This thesis also concludes that the ability of children's footwear to support children in their daily activities is generally expected to be high. However, it was also concluded that there will likely be significant challenges for fully 3D printed footwear to support children in colder weather conditions, as there is a real and perceived lack of warmth that can be provided by this product. This is an important challenge to overcome, for a system that aims to grow with users, and requires year-round product usage. Additionally, the ease of use of this product can be high, but this is expected to depend largely on the stretch around the collar area of the shoe and the child's strength. As a result, that might be a need for the addition of pull tabs that make it easier for the child to put on their own shoes. Finally, this thesis concludes that further investigation of the upper structure, as well as possible additions of removable insoles, socks or adjustable closing mechanisms is required, in order for the product to facilitate the gradual foot growth of children that occurs between two sizes, and minimize the replacement rate of 3D printed children's footwear.

With regards to circularity of the system, this thesis suggests a focus on open loop recycling or composting for the end-of-life of personalized, fully 3D printed children's footwear. This is the result of the perceived discrepancy from parents as end-users between the promise of 'personalized fit' and that of 'pre-owned footwear', and their unwillingness to engage in reuse practices around personalized 3D printed children's footwear. From a circularity point of view, this is undesirable, as the thesis suggests that currently available children's footwear is considered more suitable for reuse. However, from a health point of view, this might be desirable, as reuse of footwear might have negative effects on a child's foot development. Overall, this thesis notes that the direct health of the child is a more important factor than sustainability for parents in the selection of children's footwear. Additionally, it was suggested in this thesis that a circular system could promote rapid analysis of product performance and foot development, benefiting product development and allowing for further insights into users' gait development.

Based on user testing with parents, this thesis also concludes that there are opportunities for the creation of a circular business model on a membership basis for personalized, 3D printed children's footwear. Moreover, this thesis suggests the viability of a subscription based business model. In order to realize the proposed PSS, there is a high level of reliance on strategic partnerships, and access to user foot and fit data is of special consideration with regards to data security, and strategic positioning of LUCA as a business along the supply chain.
This thesis also argues that aesthetic customization of the physical product, namely through the addition of the child's name and production date, can provide additional value to the proposed system, and significantly increases the emotional value that can be attached to a first pair of shoes, as well as the desirability of the product as a gift. This is considered important, as gift giving might provide a good way for new users into the system. Additionally, this thesis suggests that there can be a practical value of aesthetic customization, as it might reduce the risk of product loss in settings were children temporarily take off their shoes. Such aesthetic customization would, however, further reduce chances for product reuse.

This thesis suggests that there are tensions between foot health, circularity and the level of product personalization, and these tensions are both the result of technical challenges, and of challenges related to the perceptions and values of parents. Furthermore, it reveals a distinct difference between two approaches to circularity. One seeks to create products as part of nature, highly personalized to become a true extension of the body, made of one part and able to return to nature after the first user. The other approach seeks to create products that are optimized for recirculation through the technical cycle, by use of their assembly and modularity, providing opportunities for reuse, while lowering the level of personalization.

Finally, by providing an initial concept for the development of a system that aims to provide a better understanding of the impact of footwear on foot development over time, this thesis aims to inspire and facilite a societal shift towards a more preventive and lifestyle based approach to physical and mental health care.

9.3 Personal Reflection

Reflections On The Journey

If there is one lesson that this thesis has provided me with, it is the importance of choosing 'what not to do'. As my supervisors accurately assessed in the middle of the project, I have a tendency to do everything. However, this is in conflict with another desire of mine: I want to do things very well. In a sense, all of the things that I have not done during this thesis is what allowed me to do all of the things that have been done and described in this report. I think this is also reflected in the list of recommendations for future research and development. I wish I could do all of them. But choosing 'what not to do' has been a revelation in this project. The space, time and effortlessness it provides is akin to the moment I finally took my girlfriend's advice to 'use your feet' during climbing, rather than simply powering through and dealing with the inevitable soreness later. I am proud of the balance I have struck for myself between decisiveness and openness throughout the different phases of this project.

This thesis has also confirmed the alignment of physical state, mental wellbeing and project results for me. In previous projects, I have always had moments were I would get in my own head in order to solve every problem. Even though this would often yield great results short-term, I would generally have to deal with the stress on my body and mind later. Therefore, my primary personal goal for this thesis was to find a way that I could still provide the same level of results, but do it in a way that is not detrimental for my own wellbeing. By maintaining contact with stakeholder from the very beginning of the project, and realizing that my mental state was highly dependent on my physical health, I am proud to say that I have been able to realize the project results that I had hoped for, in a way that has left me in a desirable state and with a new approach to working on projects.

Finally, I am very greatful that I was able to combine my passion for footwear, digital fabrication, health, and circular design in this project, and confirm my career goals.

Personal Learning Ambitions

Physical and digital prototyping. Throughout this project, I have engaged in physical and digital prototype creation and testing of key aspects of the proposed product-service system. The creation of physical footwear prototypes made from flexible material was a great challenge, but I was eventually successful. This newly gained experience will be helpful and directly applicable in the work I hope to do next.

Developing new skills around qualitative stakeholder research. I am happy to say that I have significantly increased my skills and experience in the field of qualitative research with stakeholders throughout this project. Through interviews and informal conversations between thirty and ninety minutes, I was able to explore user perspectives from the start of the project, and I was able to gain great insights for future concept development. Most of all, it helped me to stay out of my own head, and be based in reality, while overcoming some shyness that I had with regards to this aspect of design.

Developing a faster and more iterative design process. During this project, I was repeatedly confronted with the procedure for ethics applications. This has somewhat limited the iterativeness that I hoped to achieve in this project. However, I was still able to engage in user testing, which provided a great starting point for future research and development. Furthermore, through informal conversations with many different people, I was able to continuously assess different ideas and parts of the design.

Developing a greater understanding of behavioral science and possible design applications. During this project, I have broadened my knowledge about footwear related behavior and the interaction between parents and children, through both extensive literature research and direct interaction with end-users. This has provided new insights that I was able to apply to the design in this thesis.

Thank you for reading my thesis.
Let's see what happens next..

All the best, Kevin

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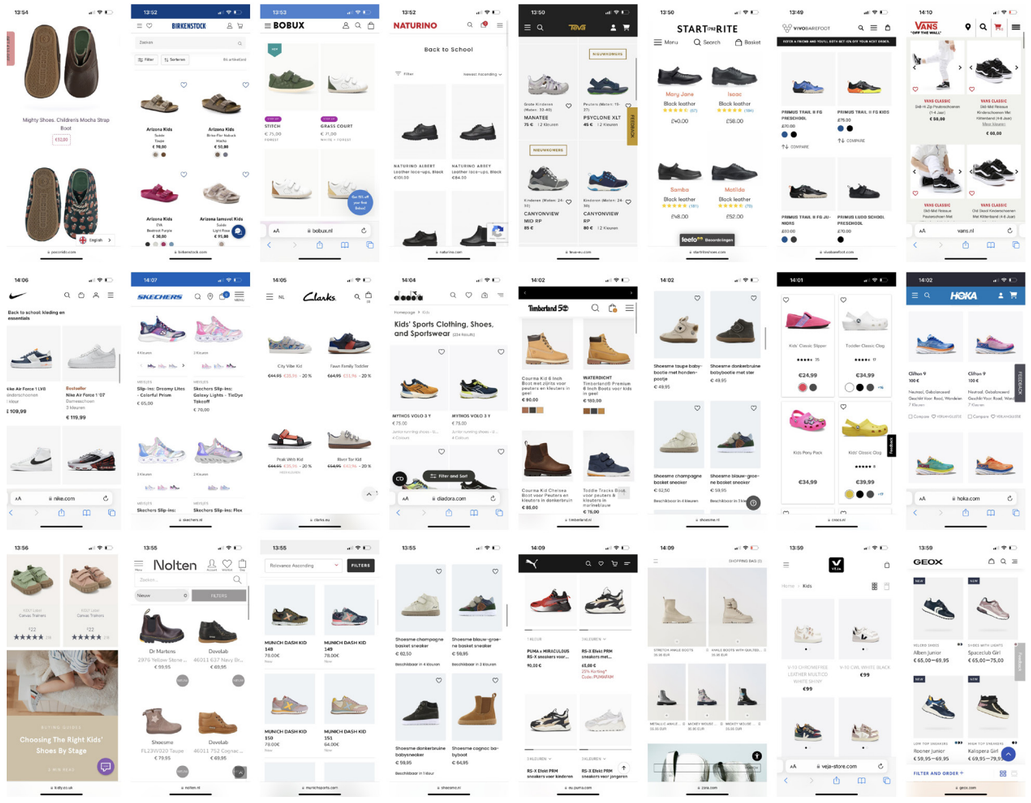
Appendix

Appendix A - Current Online & Offline Retail Spaces for Children's Footwear



Current Online Retail Environments for Children's Footwear

Current Offline Retail Environments for Children's Footwear

Appendix B - Exploratory Research Interview Guides

Dutch

Algemene Vragen:

1. Hoeveel kinderen heb je en hoe oud zijn ze?
2. Stel het begint tijd te worden om weer eens schoenen te gaan kopen voor je kind? Kijk je er tegenop of kijk je ernaar uit?
3. Hoe vaak koop je schoenen voor je kind?
    a. Is het 1 keer per maand, paar maanden, kwartaal, half jaar, jaar?
    b. Hoe lang gaan kinderschoenen ongeveer mee in jouw ervaring?
4. Wat zijn de belangrijkste redenen om nieuwe schoenen voor je kind te kopen?
    a. In hoeverre heeft dit te maken met het kapot gaan of het te klein zijn van schoenen?
5. Hoe weet je wanneer je kind uit zijn schoenen is gegroeid?
    a. Zijn er specifieke signalen vanuit je kind, waaruit jij kunt opmaken dat de huidige schoenen van jouw kind te klein of oncomfortabel zijn?
6. Hoeveel geef je over het algemeen uit aan een paar schoenen voor je kind?
    a. In hoeverre hangt dit af van het type schoenen?
7. In hoeverre zijn de behoeftes van jouw kind omtrent schoenen veranderd over tijd?
    a. Kun je je een bepaalde leeftijd herinneren waarop er belangrijke veranderingen waren in hun voorkeur voor bepaalde schoenen?
    b. Zijn er bepaalde activiteiten, zoals sporten en hobbies, die invloed hebben op het type schoenen dat je koopt?
    c. Zijn er momenten geweest waarop jouw kind vaak van schoenmaat wisselde?
    d. Moet je nog rekening houden met dingen als extra ondersteuning van de schoenen voor je kind?

Offline Retail Ervaring:

8. Kun je een recente ervaring in een kinderschoenenwinkel beschrijven?
    a. Om welke reden ging je naar deze winkel?
    b. Uit welke stappen bestond het proces van het kiezen en kopen van de schoenen?
    c. Waar was je kind mee bezig tijdens het bezoek aan de winkel?
    d. Waar was jij mee bezig tijdens het bezoek aan de winkel?
    e. Heb je hulp gekregen van een winkelmedewerker? Waarmee?
    f. Kun je een specifiek moment herinneren waarbij je tegen iets aanliep waarbij je hulp nodig had? Van een winkelmedewerker of iemand anders?
    g. Hoeveel tijd nam het bezoek aan de winkel in beslag?
    h. Waren er specifieke momenten die tot frustratie of ongemak leidden?
9. Hoe vind je in de winkel de goede schoenmaat voor je kind?
    a. Hoe makkelijk vind je het over het algemeen om de juiste maat voor je kind te vinden?
    b. Wat voor hulpmiddelen zijn er beschikbaar om de juiste maat te vinden?
    c. Hoe zeker ben je er over het algemeen van dat je de juiste maat hebt gevonden in een winkel, met of zonder hulp van een winkelmedewerker?

Online Retail Ervaring:

10. Heb je ooit kinderschoenen online gekocht? Zo ja, kun je jouw laatste ervaring daarmee beschrijven?
    a. Wat was de reden om op deze plek naar schoenen te kijken?
    b. Uit welke stappen bestond het proces van het kiezen en kopen van de schoenen?

11. Van welke online retailers of platforms maak je het meest gebruik voor het kopen van kinderschoenen?
    a. Wat is voor jou belangrijk bij het online kopen van kinderschoenen?
12. Wat voor obstakels ben je tegengekomen bij het kopen van kinderschoenen online?
    a. Hoe ging je hiermee om?
13. Hoe zorg je ervoor dat de schoenen die je online koopt ook goed passen bij je kind?
    a. Zijn er bepaalde hulpmiddelen die je daarvoor gebruikt?
14. Retourneer je vaak online gekochte kinderschoenen? Om welke reden?
    a. Hoe ziet het retour proces eruit?
    b. Hoe gemakkelijk is dit proces?

Stijl en gezondheid:

15. Is het in het verleden ooit lastig geweest om schoenen te vinden die jij en je kind mooi vonden en ook de juiste pasvorm en maat hadden?
    a. Waarom is het voor jou belangrijk dat de schoenen goed zitten? Wat is volgens jou het belang van goed zittende schoenen voor je kind?
    b. Waarom is het voor jou belangrijk dat de schoenen er goed uitzien (in jouw ogen en/of die van je kind)?
16. Wat voor effect heeft het vinden van de juiste pasvorm/maat en stijl op het aankoopproces van kinderschoenen?
    a. Heb je wel eens het gevoel gehad dat het kopen van kinderschoenen onnodig lang duurt? Of gaat het over het algemeen snel genoeg?
    b. Leidt het proces wel eens tot ongemak bij jou of je kind?
17. Hoe heb je geprobeerd dit proces makkelijker te maken?
    a. Ga je het liefst naar een fysieke winkel met hulp van een winkelmedewerker of zoek je het liefst online zodat het thuis te passen is?
18. Stel je probeert een keuze te maken tussen drie schoenen voor je kind. Optie 1 zit perfect, juiste pasvorm, goede maat en zit lekker, maar het ziet er totaal niet uit. Optie 2 zit vrij goed, en staat prima. Optie 3 staat super leuk, jij en je kind zijn allebei enthousiast, alleen de pasvorm is gewoon net niet helemaal lekker. Voor welke optie zal je waarschijnlijk kiezen? Om welke reden?

Sustainability:

19. Wat doe je met kinderschoenen die niet meer gedragen worden?
    a. Heb je ooit moeite gehad met bepalen wat je het beste met de schoenen kunt doen?
    b. Met welke reden of welk doel doe je dit?
20. Heeft je kind ooit tweedehands kinderschoenen gedragen?
    a. Hoe ben je aan deze schoenen gekomen?

Additional Questions:

21. Op wat voor manier is jouw kind betrokken bij het kiezen van de schoenen?
22. Zou je jouw perfecte shop ervaring kunnen beschrijven? Of zou je kunnen beschrijven hoe het kopen van kinderschoenen er absoluut niet uit moet zien?
    a. Zou dit in een fysieke winkel of online zijn? Waarom
    b. Op wat voor manier zou een winkelmedewerker of online klantenservice in deze ervaring een rol kunnen spelen?
    c. Hoe lang zou het hele proces duren?
    d. Wat voor gevoel zou het proces met zich mee moeten brengen voor jou en je kind?

23. Zijn er momenten geweest waarop je kind graag een specifiek paar schoenen wilde hebben?
    a. Wat was de reden dat je kind deze schoenen graag wilde hebben?
    b. Welke factoren waren van invloed hierop? Denk bijvoorbeeld aan reclame, trends, vrienden, etc.
    c. Wat voor invloed heeft dit op de uiteindelijke keuze voor een paar schoenen?
24. Zijn er nog andere externe factoren of meningen die je meeneemt in het keuzeproces? Denk hierbij aan de mening van familieleden, online reviews, culturele factoren, etc.
25. Als je kijkt naar hoe het hele kopen van kinderschoenen eraan toegaat, wat zou jij dan het liefst anders willen hebben? Waarom dat precies?
26. Is er nog iets dat je wil delen over jouw ervaring met kinderschoenen?

English

General Questions:

1. How many children do you have and how old are they?
2. Imagine it's time to buy new shoes for your child again. Are you looking forward to it or do you dread it?
3. How often do you buy shoes for your child?
    a. Is it once every month, couple of months, quarter, half year, year?
    b. In your experience, how long do your child's shoes last?
4. What are the most important reasons to buy new shoes for your child?
    a. To what extent is it related to shoes breaking down or shoes not fitting?
5. How do you know that your child has outgrown their shoes?
    a. Are there specific signs from your child that alert you to the possibility that your child's current shoes are too small or uncomfortable?
6. How much do you generally spend on a pair of children's shoes?
    a. To what extent does this depend on the type of shoes?
7. To what extent have the footwear needs of your child changed over time?
    a. Can you recall a particular age when there were significant changes in their preferences for certain shoes?
    b. Are there certain activities, such as sports and hobbies, that influence the types of shoes that you buy for them
    c. Have there been times when your child changes shoe sizes often?

Offline Retail Experience:

8. Can you describe a recent experience in a children's shoe store?
    a. For what reason did you go to this store?
    b. What steps did the process of choosing and buying a pair of shoes consist of?
    c. What was your child doing during your visit at the store?
    d. What were you doing during your visit at the store?
    e. Did you receive help from a store employee? If so, what kind of help?
    f. Can you recall a specific moment where you ran into a problem that you needed help with, from a store employee or someone else?
    g. How much time do you estimate the store visit took in total?
    h. Were there specific moments during your store visit that lead that you experienced as inconvenient?
9. Can you describe the process of finding the right shoe size for your child in the store?
    a. How easy is it for you to find the right shoe size for your child?
    b. What tools are available in the store to find the right size?
    c. In general, how confident are you that you have found the right size at the end of a store visit, with or without the help of a store employee?

Online Retail Experience:

10. Have you ever bought children's shoes online? If so, can you describe your last experience with it?
    a. What was the reason for looking at shoes in this place?
    b. What steps did the process of choosing and buying a pair of shoes consist of?
11. Which online retailers or platforms do you use the most when buying shoes for your child?
    a. What is important to you when buying shoes for your child online?
12. What obstacles have you encountered when buying shoes for your child online?

    a. How did you overcome these obstacles?
13. How do you ensure that the shoes you buy online fit the feet of your child?
    a. What tools are there for you to use to determine the right size when buying shoes online?
14. Do you often return children's footwear? If so, for what reason?
    a. What does the return process look like?
    b. How easy is this process in your experience?

Style and Health:

15. Has it ever been difficult in the past to find shoes for your child that looked and fit great?
    a. What do you think is the importance of well-fitting shoes for your child?
    b. Why is it important to you that your children wears shoes that look good?
16. How does finding the right fit and style affect the purchase process of your child's footwear?
    a. Have you ever felt that buying children's shoes takes unnecessarily long or is it generally quick enough?
    b. Does the process ever lead to discomfort or inconvenience for you or your child?
17. What are the things you have tried to make the process of finding well fitting, good looking children's shoes easier?
    a. Do you prefer to go to a physical store with help from a store associate or do you prefer to search online and try the shoes at home?
18. Suppose you have narrowed down your selection of shoes to three options: Option 1 fits perfectly, right fit, good size and it's comfortable, but it just doesn't look nice. Option 2 fits pretty well, and looks fine too. Option 3 looks awesome, however, the fit is just not quite right for your child's feet. Which option would you most likely choose and for what reason?

Sustainability:

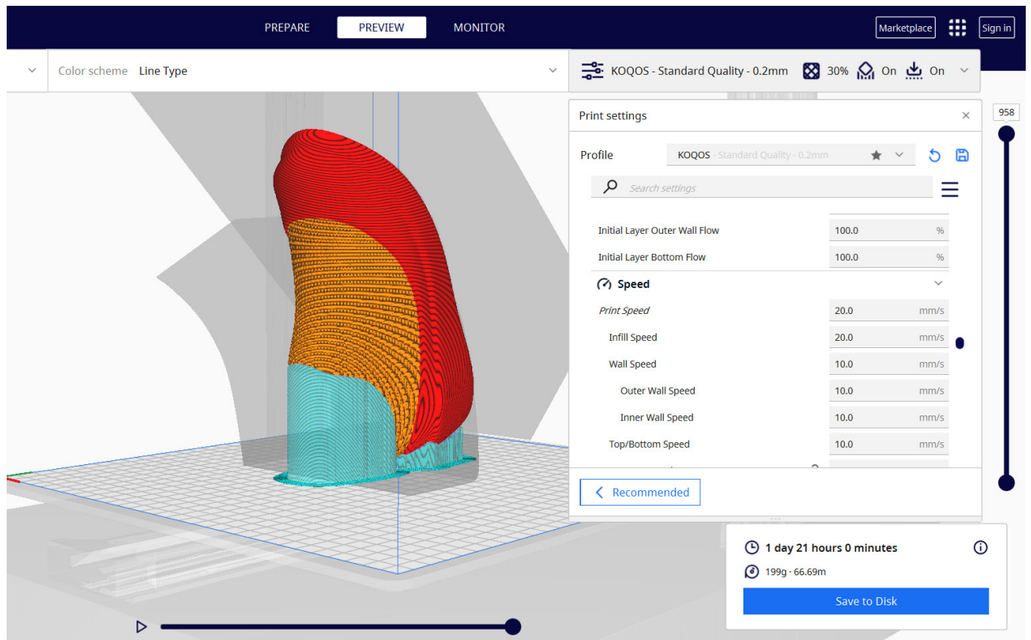
19. What do you do with children's shoes that your child no longer wears?
    a. Have you ever had trouble determining what you could you do with those shoes?
    b. For what purpose or reason do you do this?
20. Has your child ever worn second hand shoes?
    a. How did you get these shoes?

Additional Questions:

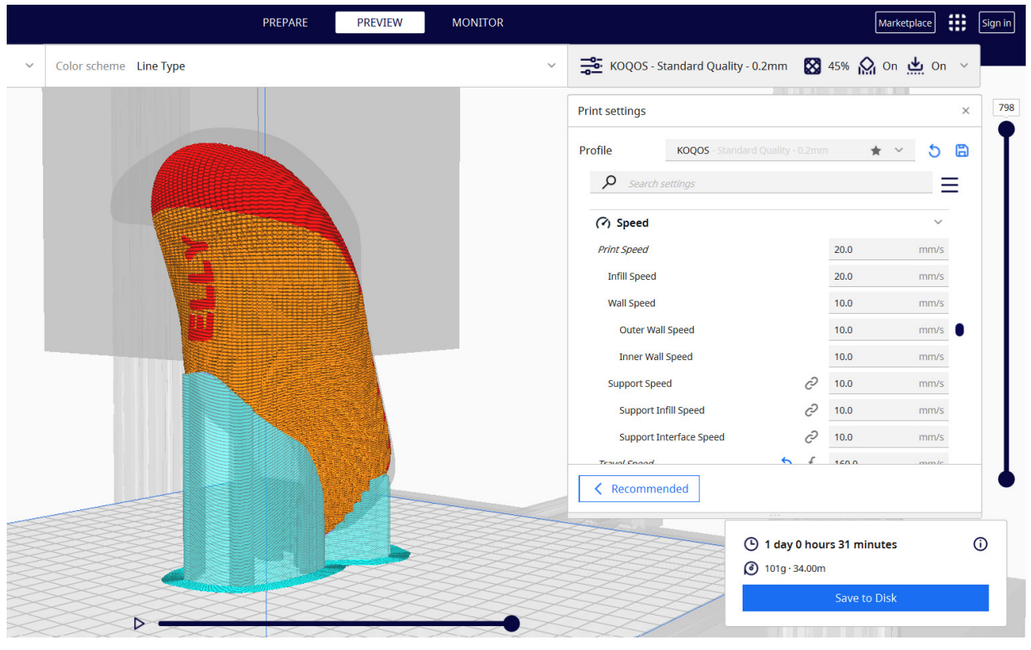
21. In what ways is your child involved in choosing shoes?
22. Could you describe your ideal shopping experience for children's footwear? Or could you describe what buying children's shoes should absolutely not be like?
    a. Would this be in a physical or online store/platform?
    b. In what ways might a store associate or online customer service representative/chat bot play a role in this experience?
    c. How much time would the entire process cost?
    d. What feeling should the process bring about for you and your child?
23. Have there been times when your child wanted a specific pair of shoes?
    a. What was the reason your child wanted these shoes?
    b. What do you think influenced this desire? Consider things like advertising, trends, social media, friends, etc.
    c. How does this affect the final choice of a pair of shoes?

24. Are there any other external factors or opinions that you take into consideration during the process of buying new shoes for your child? Consider things like the opinions of other family members, online reviews, cultural factors, etc.
25. When you look at the process of buying children's shoes or children's footwear in general, is there anything that you would like to see different? Why?
26. Is there anything else you would like to share about your experience with children's shoes?

Appendix C - 3D Printing Files in Cura



LUCA Sleek in Cura for printing with Filaflex Foamy (TPU)



LUCA Wander in Cura for printing with Filaflex Foamy (TPU)

Appendix D - User Testing Interview Guides

Dutch

Ik ben bezig met het onderzoeken van een nieuw product/service systeem voor kinderschoenen en ik zal je vandaag wat beeldmateriaal laten zien van een concept. Voor mij is het doel echt om erachter te komen in hoeverre dit concept in de huidige vorm wel of niet aansluit bij jou als ouder, zodat het concept verder verbeterd kan worden. Dus denk vooral hardop en benoem alle bedenkingen en associaties die je eventueel hebt op basis van wat je te zien krijgt.

Physieke Product

Wat je hier ziet is een collectie aan volledig 3d geprinte kinderschoenen in verschillende stijlen en kleuren. Puur op basis van wat je hier ziet, hoe zou je het product dat je ziet omschrijven? Denk lekker hardop en benoem gewoon alle indrukken en associaties die je hebt met het product dat je ziet.

1. Wat vind je van de esthetische waarde van dit product ten opzichte van bestaande producten?
2. In hoeverre denk je dat deze producten qua stijl wel of niet passen bij de kleding die je kind momenteel draagt?
3. In hoeverre denk je dat deze schoenen wel of niet geschikt zijn om je kind te ondersteunen in zijn/haar dagelijkse activiteiten?
    a. Denk je dat dit product wel of niet voldoende bescherming kan bieden voor de voeten van jouw kind?
    b. Denk je dat dit product wel of niet voldoende ondersteuning kan bieden voor de voeten van jouw kind?
    c. Denk je dat dit product wel of niet voldoende comfort kan bieden aan de voeten van jouw kind?
    d. Denk je dat dit product tegen een stootje kan en lang meegaat of niet echt?
4. Zou dit product moeilijk of makkelijk in gebruik zijn?

Jouw Eerste Schoenen

Om het eerste paar schoenen van een kind extra speciaal te maken zou het bijvoorbeeld mogelijk zijn om een naam en datum toe te voegen aan de schoenen. Zouden dit soort mogelijkheden nog van toegevoegde waarde zijn voor jou als ouder?

5. Zou je zoiets als cadeau geven aan iemand met een jong kind?
6. Zou je zoiets leuk vinden om als cadeau van iemand te ontvangen?

Winkelervaring

Ik zal nu wat meer informatie geven over het aankoopproces van dit product en dan zal ik vervolgens weer een aantal vragen aan je stellen. Het aankoopproces begint eigenlijk net als bij andere kinderschoenen. Je kunt online de beschikbare stijlen en kleuren bekijken en eventueel een soort selectie maken van mogelijke opties. De volgende stap wijkt echter af van huidige kinderschoenen. Normaal zou je nu een maat zou kiezen, online of in een winkel. Deze 3d geprinte kinderschoenen worden echter pas gemaakt wanneer jij een bestelling hebt geplaatst en de maat wordt automatisch bepaald op basis van de breedte en lengtemaat van de voeten van jouw kind.

Om de maten van je kind snel en precies vast te leggen is er een winkelbezoek nodig. Dit winkelbezoek bestaat uit twee stappen. In stap 1 staat jouw kind op een voet scanning platform en wordt door een karakter op een scherm meegenomen door het scanningproces.

In stap 2 veranderd het scherm met het karaktertje in een magische spiegel die de schoentjes van jouw keuze projecteert op de voeten van jouw kind. Vervolgens kan er een schoen worden gekozen en wordt deze geproduceerd en thuis afgeleverd.

7. In hoeverre spreekt deze winkelervaring u wel of niet aan voor het kopen van kinderschoenen?
8. In hoeverre denk je dat deze winkelervaring wel of niet kan leiden dat goed passende kinderschoenen?
9. Zou deze winkelervaring het makkelijker of moeilijker maken voor u om samen met uw kind schoenen te kopen, in vergelijking met uw huidige manier van kinderschoenen kopen?
10. Zou deze winkelervaring het makkelijker of moeilijker maken om een paar schoenen te kiezen?
11. Wat vindt u een acceptabele wachttijd voor zo'n paar 3d-geprinte kinderschoenen?

Collectie en Hergebruik

Oude gedragen schoenen kunnen na gebruik ook weer worden ingeleverd in de winkel en deze worden dan door het bedrijf gewassen en geïnspecteerd om te bepalen of deze nog kunnen worden hergebruikt of moeten worden gerecycled.

12. Zou u van deze service gebruikmaken?
13. Zou u zelf overwegen om dit product tweedehands te kopen?

Overige Reflecties

Tot slot heb ik nog een paar algemene vragen met betrekking tot het product en service systeem dat je vandaag hebt gezien. Ten eerste zou ik graag weten of er aspecten van dit concept zijn die jou extra aanspreken of aspecten die je juist onwenselijk vindt?

14. In hoeverre denk je dat dit product een positieve of negatieve invloed op de gezondheid en ontwikkeling van de voeten van uw kind?
15. Vind u dit concept meer of minder milieu en sociaalverantwoord dan bestaande producten?
16. Ik ben momenteel bezig met het ontwikkelen van prototypes van de schoenen en winkelervaring, waarbij ik ouders met hun kind door een kleine simulatie van het winkelproces mee wil nemen. Zou je daar ook aan mee willen doen?

English

I am researching a new product/service system for children's shoes and today I will show you some images of a concept. For me, the goal is really to find out to what extent this concept in its current form does or does not connect with you as a parent, so that the concept can be further improved. So simply think out loud and name any reservations and associations you may have based on what you see.

Physical Product

What you see here is a collection of fully 3d printed children's shoes in different styles and colors. Based purely on what you see here, how would you describe the product you see? Think out loud and just name all the impressions and associations you have with the product you see.

1. What do you think about the aesthetic value of this product compared to existing products?
2. To what extent do you think these products fit or don't fit with the current clothing style of your child?
3. To what extent do you think these shoes are or are not suitable to support your child in his/her daily activities?
    a. Do you think this product can or cannot provide sufficient protection for your child's feet?
    b. Do you think this product can or cannot provide adequate support for your child's feet?
    c. Do you think this product can or cannot provide enough comfort for your child's feet?
    d. Do you think this product would be durable or not really?
4. Would this product be difficult or easy to use?

Your First Shoes

To make a child's first pair of shoes extra special, it would be possible to add a name and date to the shoes. Would such options provide additional value to the product for you as parent?

5. Would you give something like this as a gift to someone with a young child?
6. Would you like to receive something like this as a gift from someone?

Shopping Experience

I will now give some more information about the purchase process of this product and then I will again ask you some questions. The purchase process actually begins just like other children's shoes. You can look at the available styles and colors online and possibly make some sort of selection of possible options. However, the next step differs from current children's shoes. Normally, you would now choose a size, either online or in a store. However, these 3d printed children's shoes are not made until you place an order and the size is automatically determined based on the width and length measurements of your child's feet.

To determine your child's measurements quickly and accurately, a store visit is required. This store visit consists of two steps. In step 1, your child stands on a foot scanning platform and is taken through the scanning process by a character on a screen.

In step 2, the screen with the character turns into a magic mirror that projects the shoes of choice onto your child's feet. A shoe can then be ordered, after which it is produced and delivered to your home.

7. To what extent does or doesn't this shopping experience appeal to you for buying children's shoes?
8. To what extent do you think this shopping experience may or may not lead to well-fitting children's shoes?
9. Would this shopping experience make it easier or harder for you to buy shoes together with your child, compared to your current way of buying children's shoes?
10. Would this shopping experience make it easier or harder to choose a pair of shoes?
11. What do you think is an acceptable waiting time for a pair of personalized 3d printed children's shoes?

Collection and Reuse

Old worn shoes can also be returned to the store after use and they will be washed and inspected by the company to determine if they can still be reused or should be recycled.

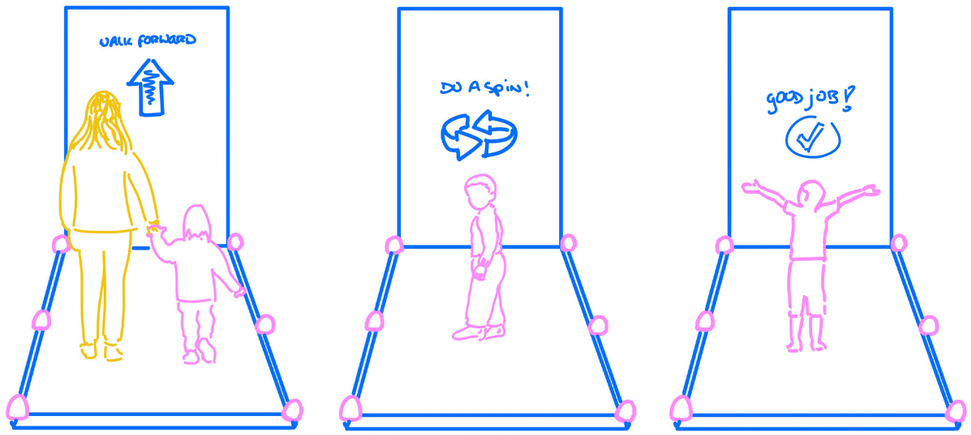
12. Would you consider using such a service?
13. Would you consider buying these shoes second hand?

Additional Reflections

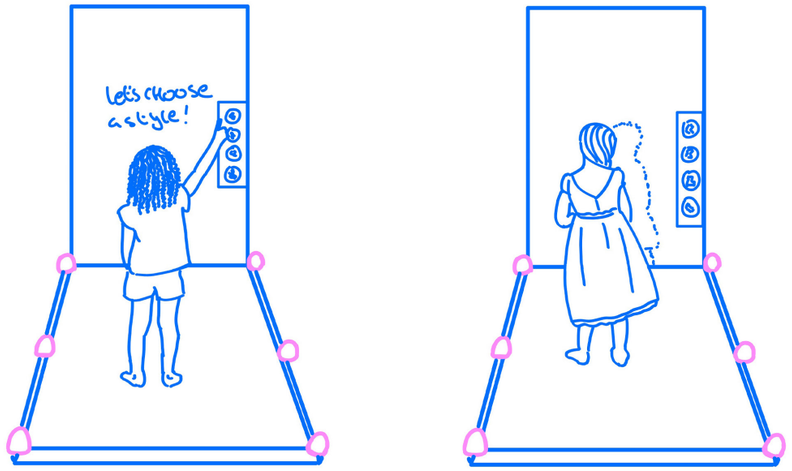
Finally, I have a few general questions regarding the product and service system you saw today. First, I would like to know if there are aspects of this concept that you find particularly appealing or aspects that you find undesirable?

14. To what extent do you think this product has a positive or negative impact on the health and development of your child's feet?
15. Do you think this concept is more or less environmentally and socially responsible than existing products?
16. I am currently developing prototypes of the shoes and shopping experience, which I want to use to take parents with their child through a small simulation of the shopping process. Would you like to participate in that as well?

Appendix E - Sketches of Store Interactions



Interactions for foot scanning procedure



Interactions for style selection procedure

Appendix F - Project Brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Mac Donald
initials: K.S. given name: Kevin
student number: 4668979
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): ( ) IPD ( ) Dfl (★) SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ( ) Honours Programme Master
specialisation / annotation: ( ) Medisign ( ) Tech. in Sustainable Design ( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Lise Magnier dept. / section: MCR
** mentor: Jo van Engelen dept. / section: DfS
2nd mentor:
organisation:
city: country:
comments (optional):

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair Lise Magnier date 22 - 09 - 2023 signature Lise Magnier Digitally signed by Lise Magnier Date: 2023.09.25 17:28:58 +02'00'

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 42 EC
Of which, taking the conditional requirements into account, can be part of the exam programme 30 EC
List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed
NO missing 1st year master courses are:

name Robin den Braber date 26 - 09 - 2023 signature Robin den Braber Digitaal ondertekend door Robin den Braber Datum: 2023.09.26 15:30:50 +02'00'

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED
Procedure: ★ APPROVED NOT APPROVED

comments

name Monique von Morgen date 27 - 09 - 2023 signature Monique von Morgen Digitally signed by Monique von Morgen Date: 2023.09.27 10:57:11 +02'00'

Personal Project Brief - IDE Master Graduation

Promoting foot health of children through footwear as a service — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 13 - 09 - 2023 12 - 02 - 2024 end date

INTRODUCTION **
Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Parents are making important decisions about foot health and long-term mobility every time they buy new shoes for their children. There is a tension between two important functions of modern footwear: correct fit and support on the one hand, which is crucial for healthy foot growth, and on the other hand aspects related to aesthetics and our desire for self-expression and style. At footwear retailers, the offering of different styles and colors is immense, but the availability of sizes that deviate from traditional standards is limited. A focus on the aesthetic qualities of modern footwear is also reflected in the limited knowledge modern retail employees in footwear have about appropriate fit and support. Custom made footwear might provide the right fit combined with the desired aesthetic, but for most consumers this is not a viable option. The fields of orthotics and barefoot shoes are both focused on offering footwear solutions that help people to overcome certain foot and mobility related challenges. However, these solutions are faced with a variety of challenges. They suffer from a poor image, less desirable looks and limited choice. Additionally, there are a lot of unknowns with regard to the impact of footwear on our feet. This is demonstrated by the difference in approach between the fields of orthotics and barefoot shoes. Where barefoot shoes are created with minimal support to allow for natural movement and strengthening of the foot, the field of orthotics uses additional inserts that help support the feet and improve foot posture. These fields fundamentally disagree about the best approach to healthy feet and long-term mobility.
A major development in the footwear industry is that of large scale additive manufacturing. A growing number of organizations and individuals is working on further developing and commercializing fully wearable, 3D printed footwear. In combination with 3D scanning, this technology could offer breakthroughs when it comes to creating personalized footwear that shapes to the feet of the user, instead of the other way around. The resulting product is often made from a single material and is considered fully recyclable. However, the commercialization of personalized 3D printed footwear also means that business models should be designed to fully tap into its potential with regard to foot health and choice, as well as help to accelerate the shift towards a circular footwear industry. This means thinking about the different end-of-life streams as presented by the Ellen MacArthur Foundation, as well as local for local production. Additionally, the transition towards the economy as a distributed network with interlinked processes and resources, as proposed by Kate Raworth, is a framework that could be used in this context to optimize the use of (recycled) material resources involved in creating 3D printed footwear and deal with the material property limitations that are linked to recycling thermoplastics.
Opportunities within this project lie in the possibility to get a better understanding of the psychological and physiological needs, as well as current and potential future consumer behavior and habits around children's footwear. The project aims to develop a strategic design solution that changes the interaction and relationship between end-users, children's footwear and foot health. Insights from this project could inspire footwear researchers, designers, brands and retailers to reconsider the concept of children's footwear and aid in a pursuit to create systems that harmoniously blend ergonomics and aesthetics with a long-term view on health. New ideas for circular business models in footwear could also benefit on-going research at the faculty of Industrial Design Engineering at TU Delft and its Circular Design Lab. Based on opportunities and touch points this project has with current industry developments, footwear manufacturers and research institutes specialized in digital fabrication, as well as footwear technology innovators specializing in advanced fit and sizing solutions could be considered stakeholders. Limited time and money is available for this project, and given the potential for direct research with children, extra care is needed to ensure all necessary ethical approvals are obtained. Gaps in personal knowledge necessary for the completion of this project are expected to be overcome by involving the relevant experts into the project.

space available for images / figures on next page

introduction (continued): space for images

TO PLACE YOUR IMAGE IN THIS AREA:
- **SAVE THIS DOCUMENT TO YOUR COMPUTER AND OPEN IT IN ADOBE READER**
- **CLICK AREA TO PLACE IMAGE / FIGURE**

PLEASE NOTE:
- **IMAGE WILL SCALE TO FIT AUTOMATICALLY**
- **NATIVE IMAGE RATIO IS 16:10**
- **IF YOU EXPERIENCE PROBLEMS IN UPLOADING, COVERT IMAGE TO PDF AND TRY AGAIN**

image / figure 1:

TO PLACE YOUR IMAGE IN THIS AREA:
- **SAVE THIS DOCUMENT TO YOUR COMPUTER AND OPEN IT IN ADOBE READER**
- **CLICK AREA TO PLACE IMAGE / FIGURE**

PLEASE NOTE:
- **IMAGE WILL SCALE TO FIT AUTOMATICALLY**
- **NATIVE IMAGE RATIO IS 16:10**
- **IF YOU EXPERIENCE PROBLEMS IN UPLOADING, COVERT IMAGE TO PDF AND TRY AGAIN**

image / figure 2:

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Our long-term mobility and foot health are impacted by the shoes we wear early in life. Previous studies have found that shoes significantly impact the gait and foot motion of children (Wegener et al., 2011; Wolf et al., 2008) and this could have long term consequences for motor learning and health later in life (Hollander et al., 2017). Wearing footwear with insufficient length during childhood is especially associated with foot deformities (Klein et al., 2009). It is therefore critical to carefully consider the footwear that is used by children. Furthermore, with regard to sustainability, this group has a challenge that is specific to this age range: children physically outgrow their shoes, creating a constant need for replacement. This offers opportunities for the development of design solutions and new types of business models in footwear that address these challenges. Focusing on young footwear consumers and new parents can also offer possibilities to shape healthy and sustainable behavior around footwear consumption early on.
Therefore, to limit the scope of the project, this project focuses on young children, between the ages of 1 and 12 years old, and their parents as decision-makers.
Different technological developments will play an important role in this project. These include developments in additive manufacturing and 3d scanning for customized footwear. Finally, the topic of sustainability will be adressed through the Circular Economy framework proposed by the Ellen MacArthur Foundation and the ideas proposed by Kate Raworth around distributed networks. This project seeks to find solutions for a future context that facilitate parents and children to buy the footwear they want without compromising on the child's foot health and long-term mobility. Outcomes of the project will be validated by relevant experts in the fields of circular design, footwear innovation and consumer behavior. The result of this project will ultimately be assessed on its desirability, feasability and viability.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

I want to design a circular product-service system for 3d printed footwear that helps parents and children to buy the footwear they want without compromising on the child's foot health and long-term mobility. This project will focus on gaining insights into current and future children's footwear consumption behavior and retail experience of the target group. Additionally, it explores new customer segments and circular business models for 3d printed footwear.

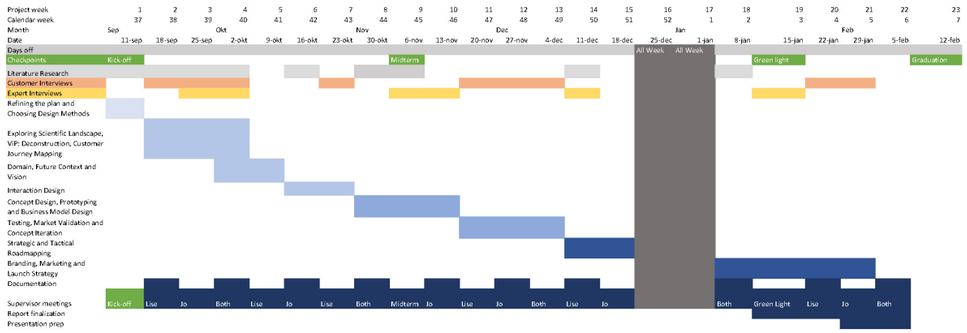
At the end of this graduation project, I aim to deliver a new circular product-service system for 3d printed footwear that helps parents and children to buy the footwear they want without compromising on the child's foot health and long-term mobility. The final deliverable will consist of the following elements:

- A clear vision statement that is user-centric, future oriented and aligned with current trends and long-term developments
- A physical and/or digital prototype that is aligned with the vision and demonstrates key functions or interactions of the proposed product-service system
- A detailed circular business model accompanying the proposed product-service system that structures the costs and revenues and is aligned with circular economy principles
- A branding, marketing and product launch strategy that effectively communicates the product-service system to the target group
- Market validation to assess the desirability of the product-service system with the target group
- A strategic and tactical roadmap that aligns short-term actions with long-term goals and provides a structured, clear and actionable plan for product development
- A final presentation/demonstration
- A report that details the process and project outcomes

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 13 - 9 - 2023 12 - 2 - 2024 end date



The first week of this graduation project mainly consists of further specifying the tasks to be done during this project. This is done by doing literature research into books around Strategic Design to refamiliarize myself with the topics and methods learned over the past years during my studies at the faculty of IDE. The next month is used to improve my knowledge and understanding of the problem context and current state of children's footwear, foot health and consumption behavior through literature research, customer interviews and expert interviews. Following the ViP design method, I will then focus on designing a future context and formulating a vision, before designing the desired future interactions. The next phase consists of the product-service system concept design, along with the design of an accompanying circular business model. After a process of three weeks, there is another three week phase where I am engaging with the target group to receive feedback on the developed concept through prototypes and scenarios that demonstrate key functions of the design. Rapid iteration and refinement of the design is done throughout this phase. Afterwards, roadmaps are created to outline the necessary steps for development of the proposed design concept in multiple phases. The final month will consist of creating and testing a branding, marketing and launch strategy for the concept. Documentation of the process will be done on a bi-weekly basis.

A two week christmas break is also implemented into the schedule. The following important dates should be noted:
- Kick-off Meeting takes place in calendar week 37, Wednesday September 13, 2023.
- Midterm Evaluation takes place in calendar week 45, around November 6-10, 2023.
- Green Light Meeting takes place in calendar week 3, around January 15-19, 2024.
- Submitting deliverables in calendar week 6, Monday February 5, 2024.
- Graduation ceremony is aimed at Monday February 12, 2024.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

Motivations:
1. Personal passion for footwear and professional ambitions in the industry
2. Personal experience with foot and mobility related challenges
3. Personal experience with health related challenges and alternative, more holistic and preventive approaches to health care
4. Personal interest in the field of circular design

Competences to prove:
1. Demonstrate in-depth industry knowledge of the footwear industry
2. Demonstrate competence in the field of circular design
3. Demonstrate the ability to create actionable long-term product development strategy
4. Demonstrate the ability to create a design that is based in reality and relates to current industry and market developments
5. Demonstrate knowledge about branding, marketing and product launch strategy
6. Demonstrate knowledge about digital fabrication for footwear
7. Demonstrate ability to work with a wide variety of stakeholders and relevant experts

Skills to improve:
1. Physical and/or digital prototyping skills. During this project, I will create a variety of physical and/or digital prototypes for the product-service system that I develop, to validate specific parts of the proposed design solution and turn ideas into tangible solutions that are easy to understand and communicate.
2. Developing a faster and more iterative design process. During this project, I will study and apply LEAN Startup methodology to quickly build prototypes, collect data on usage and effectiveness and analyze the data to know where and how to iterate on the proposed solution.
3. Developing new skills around qualitative stakeholder research. During this project, I will actively seek and maintain good contact with relevant stakeholders and engage in in-depth interviews and user testing to iterate on the solution proposed in this project.

Personal learning ambition:
1. Developing a greater understanding of behavioral science and possible design applications. During this project, I will be extending my theoretical knowledge on this topic through literature research. Additionally, I will apply this knowledge into the concepts that I design for this project.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

TU Delft

Master Thesis
Strategic Product Design
Delft, The Netherlands
February, 2024

WALK WITH RESPECT WALK WITH