Assistive technology for the visually impaired: How to provide independence and ease to meal preparation?

Master degree in Product Design Engineering

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Abstract

Disabilities are a reality many don’t think about too much unless one, or someone one knows, is affected by them. This work is motivated by this fact and is focused on attempting to improve the quality of life (QoL) of persons with visual impairment or blindness by facilitating the execution of one of the activities of daily living (ADL) – cooking independently. As this work will show, cooking with severe sight loss could prove easier or more difficult depending on various factors, the main one of which is time spent living with limited sight and, of course, proclivity for this activity. Easier, however, not easy. This is why the subject of this work is to provide a set of reliable, simple, and easy to use dispensers for oil and spices equipped with elements for identification of the various products.

In order to, offer adequate results, this work began with contextualizing the target market by presenting statistics. This was followed by a glimpse of the reality of living with the limitations of visual impairment by examining the neural pathways that allow for multisensory processing (MP) and how that applies in the investigation and development of sensory substitution devices (SSD). Leaving the purely scientific and experimental part, this work proceeded to examining the evolution of assistive technology throughout the centuries and concluded by analyzing the current products on the market today. This analysis led to the compiling of plausible hypotheses for the solutions proposed by the author followed by final proposals and the development of proof-of-concept prototypes. The work concluded by presenting a business plan around the proposed products.

Keywords: assistive technology, vision impairment, quality of life, cooking.

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List of Abbreviations and Acronyms

ADL	Activities of Daily Living
IADL	Instrumental Activities of Daily Living
MP	Multisensory Processing
QoL	Quality of Life
SSD	Sensory Substitution Device
WHO	World Health Organisation
3D	3 dimensional

1. Introduction

Home. Home is a place of comfort and safety. More than fourteen thousand years ago, the discovery of agriculture revolutionized human life on Earth. For the first time, hunter-gatherers began settling, as opposed to constantly traveling, and with that gave birth to the concept of permanent homes [1]. Since then, humanity has spent tens of thousands of years perfecting it, creating ways to make it warmer, simpler, more and more comfortable. Starting in caves and hubs with no windows or doors, constantly working on the space that it is today with complex layouts, specified rooms etc. Every day designers, architects, celebrities and media personalities offer more and more ideas on how to make this one space as comfortable and as personalized as possible. It is difficult not to notice that lately, the majority do not have

the purpose of solving a problem that has never been solved before, but instead are focused on simplifying more and more already existing solutions for our comfort.

One large minority of the population, however, does not profit from most of these updates and that is 40% of the world population [2]. Constituting the largest minority on this planet, people with disabilities or temporarily reduced mobility are at worst not considered or at best must be content with limited solutions to the obstacles they encounter in the day to day [2]. Often the popular opinion in regard to the development of more, better or different variations to the same product, that designers are confronted with is summarized by the belief that since a certain problem has already been resolved once there is no need to improve or provide better solutions.

1.1. Contextual relevance

According to the World Health Organization (WHO) there are around 285 million visually impaired people, almost 40 million blind and another more than 245 million people with low vision as it is shown in table 1. More than half of the visually impaired and low vision population is above 50 years old [2]. It is estimated that in Europe 3% of the population lives with some degree of sight loss and a total estimate of more than 30 million blind and partially sighted people of whom a large majority is considered to be senior citizens [3].

Table 1 – Number of people visually impaired and corresponding percentage of the global impairments by WHO Region and county, 2010 [2].

		Blindness	Low vision	Visual Impairment
Region	Total population in millions (%)	No. in millions (% of total population)	No. in millions (% of total population)	No. in millions (% of total population)
Africa	**804.9 (11.9%)**	**5.888 (15%)**	**20.407 (8.3%)**	**26.295 (9.2%)**
America	**915.4 (13.9%)**	**3.211 (8%)**	**23.402 (9.5%)**	**26.612 (9.3%)**
Eastern Mediterranean	**580.2 (8.6%)**	**4.918 (12.5%)**	**18.581 (7.6%)**	**23.499 (8.2%)**
Europe	**889.2 (13.2%)**	**2.713 (7%)**	**25.502 (10.4%)**	**28.215 (9.9%)**
South-East Asia region (India excluded)	**579.1 (8.6%)**	**3.974 (10.1%)**	**23.938 (9.7%)**	**27.913 (9.8%)**
Western Pacific Region (China excluded)	**442.3 (6.6%)**	**2.338 (6%)**	**12.386 (5%)**	**14.724 (5.2%)**
India	**1181.4 (17.5%)**	**8.075 (20.5%)**	**54.544 (22.2%)**	**62.619 (21.9%)**
China	**1344.9 (20%)**	**8.248 (20.9%)**	**67.264 (27.3%)**	**75.512 (26.5%)**
World	**6737.5 (100%)**	**39.365 (100%)**	**264.024 (100%)**	**285.389 (100%)**

Why is it so important to cater to the needs of this minority? It appears that, since ancient Greece, sight has been the sense most revered. In the Metaphysics, Aristotle speaks about how the yearning for knowledge can be equated to the joy of vision [4]. From then on, sight has been considered to be the most important sense people possess with the closest relation to having a good life or high quality of life (QoL). For the purposes of this work QoL is closely related to the ability to easily and independently execute the basic Activities of Daily Living (ADL) which are divided into the following categories [5]:

- Ambulating – the capacity of an individual to change positions and walk freely;
- Continence – the ability to properly control one's bladder and bowels and adequate use of facilities (sometimes combined with Toileting);
- Dressing – the ability to adequately select and put on appropriate clothing;
- Feeding – the ability to feed oneself without assistance;
- Personal hygiene – the ability to bathe and maintain oral, nail and hair care for oneself

Among the reasons for an individual's inability to fully execute the basic ADLs are musculoskeletal, neurological and sensory conditions [5]. Visual impairment clearly falls into the domain of sensory conditions impeding the performance of ADLs thus implying a lower QoL. This work attempted to provide help in the solution of the fourth category ADL: Feeding. Visual abilities and QoL are correlated in that when the former improves so does the latter [6]. Moreover, lower vision related to QoL is closely linked to reduced locomotor function due to visual impairment [7, 8]. This proves that enriching the market with more and more tailored solutions is not only a matter of a niche market that has still been left unexplored to its full potential but it is also a matter of potentially aiding in the improvement of QoL for people with visual impairment, as statistics suggest that very few will not be affected to some degree at some point during their lifetime.

1.2. Aims and motivation

The aim of this thesis is to firstly shed light on the day-to-day experiences of people with visual impairments. By examining the predominant conditions, manifestations and circumstances for sight loss and the effect it has on the life of the affected population, it was hoped to inspect the areas where the triviality of everyday life can be facilitated thus improving the QoL of millions of people worldwide. The focus of this thesis is to simplify the

cooking process and the final aim is to increase the independence level of a significant portion of the population.

The drive behind this work is a combination of concluding that there is a market niche which has not yet been developed to its full potential and the personal challenge it poses. After a careful examination of the market of assistive technology it has been concluded that while one can find a variety of products online there are several weak points worth focusing on. For instance, if one is in North America, the United Kingdom, the Scandinavian peninsula or Germany, one can take one's pick at a much more diverse pool of options than if one lives in Portugal for example. And this is reflected even more dramatically in physical specialized stores. With this in mind it seemed sound to attempt to enrich the market with more specialized accessible products so as to balance the variety of choice between the market of assistive products and the mainstream market; which every day is flooded by more and more devices with extremely specific applications and functions.

Knowing how many people live with visual impairment and knowing that for most of the population it will be difficult to avoid this (age related sight deterioration) it is obvious that if the market were more diverse then the QoL of most will eventually improve. Ultimately what this work aims to do is to contribute to the development of the assistive technology market by supplying it with an accessible, innovative, adaptable alternative at a reasonable price. The details of how this work approached this objective follow below.

1.3. Thesis structure

This work starts by contextualizing what home represents, setting it distinctly apart from the simple four walls and a roof structure and highlighting all the underlying sentiments involved with this word. Ever since man developed tools, man has been on a never-ending quest to perfect this space associating with it above all else the feelings of security and comfort. For this is precisely the reason this work begins there, followed by the observation that these two basic feelings are not experienced by the biggest minority in the world: the differently abled, of which specific to this work are the visually impaired.

It is expanded on by discussing how many people suffer from visual impairment and blindness worldwide therefore providing context and relevance to this work. In order to accomplish the aims of this work it will begin with a full overview of what is visual impairment in chapter 2. It is divided into two main parts- first, the focus will fall on the latest methods and

advancements in the field of neuroscience and how the brain copes with and adapts to these deficiencies through the processes of MP, spacial cognitive mapping and the investigative work done with SSD. After the examination of these more medical and scientific aspects of this topic, it will be proceeded by a more practical approach i.e. examine testimonials from blind and visually impaired chefs. This will lead into Chapter 2.3 where in order to provide context to the field, a brief inspection of the evolution of assistive technology for the blind in broader terms and then focus on the latest advancements in the area of assistive products for the kitchen.

Subsequent to an analysis of these products, the work will move onto Chapter 3 where the product development will unfold starting by a review of the requirements and a presentation of the hypotheses for both the oil dispenser and indicator pour spout as well as the spice dispenser. Following will be a description of the success or failure of the first set of prototypes and analysis of the results.

Chapter 4 will be presenting the final design concepts for both products with the accompanying evaluation by functionality, ergonomics and presentation. The final concepts will feature design details based on all the specifications made clear in prior chapters. These designs will incorporate elements for easy differentiation based on touch and color-contrast which will provide opportunities for customization and useability.

Furthermore, once the final concepts are presented this work will be expanded on by adding the practical to the theoretical in that it will be explaining how these products can reach their target. This is done by giving a look at what production will entail and what would a business built around these two products will be like. Given how the idea behind this work is to help people, the business will follow that same belief and not be one strictly for profit. The business model will expand on these notions and explain how this could be possible by working with sponsors and other policies.

Finally, this work will conclude by an analysis on what has been accomplished. This part will also include a breakdown of the successes and limitations of the results by providing insight on which aspects and in which ways can be improved. Furthermore, it will feature proposals on future works related to this one as potential concepts for more similar products.

1.4. Conclusion

Sight is crucial to the feeling of independence and self-reliance in any individual. Considering the overwhelming number of the world population living with some degree of sight loss and the obstacle this presents in people with a high degree of visual impairment, the author deemed it an important topic to explore. Since this work will concentrate on the improvement of QoL of people with severe visual impairment in the area of independent meal preparation, next is a review of the common causes for visual impairment and sight loss, followed by a dive into the world of assistive technology since its beginnings until nowadays.

2. Visual impairment and assistive technology: a review

For it to be possible to find the appropriate solution to the problem hereby presented it is of crucial importance to study and comprehend the microcosm that is visual impairment. Through a thorough analysis of the market target it was possible to make the adequate design decisions in the later stages of development.

What is commonly known about visual impairment is usually quite limited and misrepresented, from the percentile of affected individuals to the varied characteristics of these affectations. First, it is of value to know how many people live with severe visual

impairments. Worldwide, there are 1.3 billion people with some degree of visual impairment as estimated by WHO, a prognosis suggests that with the ageing of the population will grow at an important rate in the upcoming decades as the population which is affected the most is over the age of 50 years old [2]. The estimated number for the European population to date is approaching 30 million individuals. This chapter explores the related motor limitations of persons with visual impairment, what is MP and how does sensory substitution function. The latter is of particular importance to this work as it is the concept which the design will be based on.

2.1.Multisensory processing and sensory substitution

Introduction

Humans and animals alike interact with their environment thanks to the fact that the brain is capable of multisensory integration of data, meaning that the brain accumulates cues from the five senses (sensory modalities) and processes that information accumulatively to allow to perceive surroundings and behave accordingly. Although there is ample literature on the topic of multisensory processing in adults not much is known in the development of these processes in adulthood. One of the main questions is how and why the various sensory modalities stimuli interact with each other [9]. To be able to better explain and introduce multisensory processing, is a look at a map of the human brain showing the motor and sensory regions in figure 1 [10] where it can be observed that the association areas are much larger than the primary areas, as it is most evident in the primary sensory cortex and the somatic sensory association area. Although size comparison may be completely irrelevant to functional capabilities, in this case it is a welcome coincidence as it does illustrate the capability of the human brain to form associations between all types of stimuli, which is the foundation concept of this work. An example of the connections made in MP can be seen in an illustration of the basic concept in figure 2 where diverse difficulties of a simultaneous processing of visual and auditory stimuli is observed [11]. It shows how the information gathered through sight and sound is combined in a comprehensive perception of space.

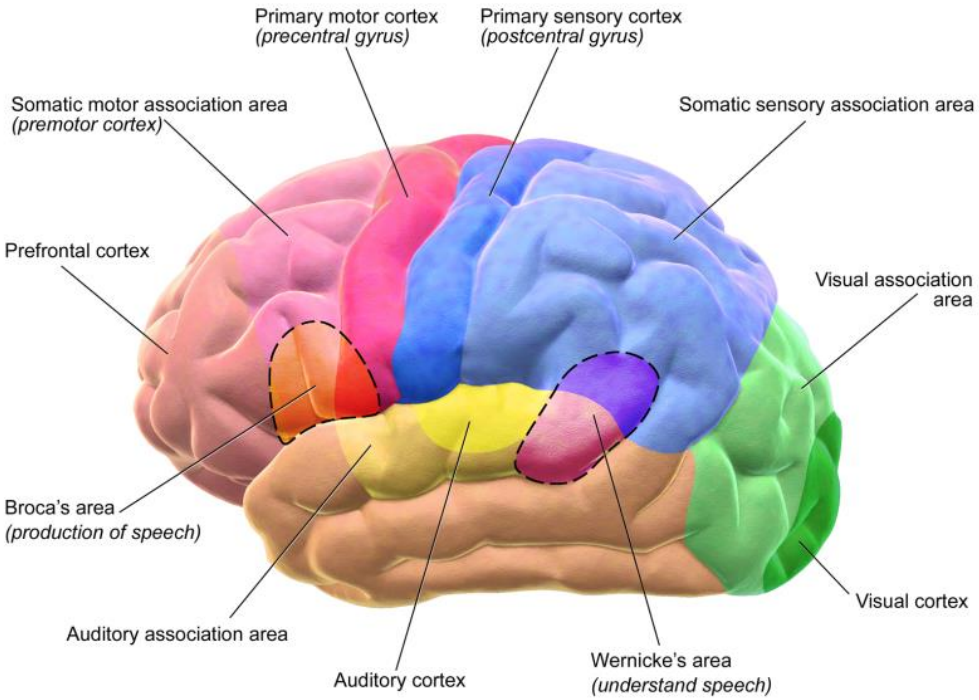

Figure 1 – Map of the motor and sensory regions of the cerebral cortex [10].

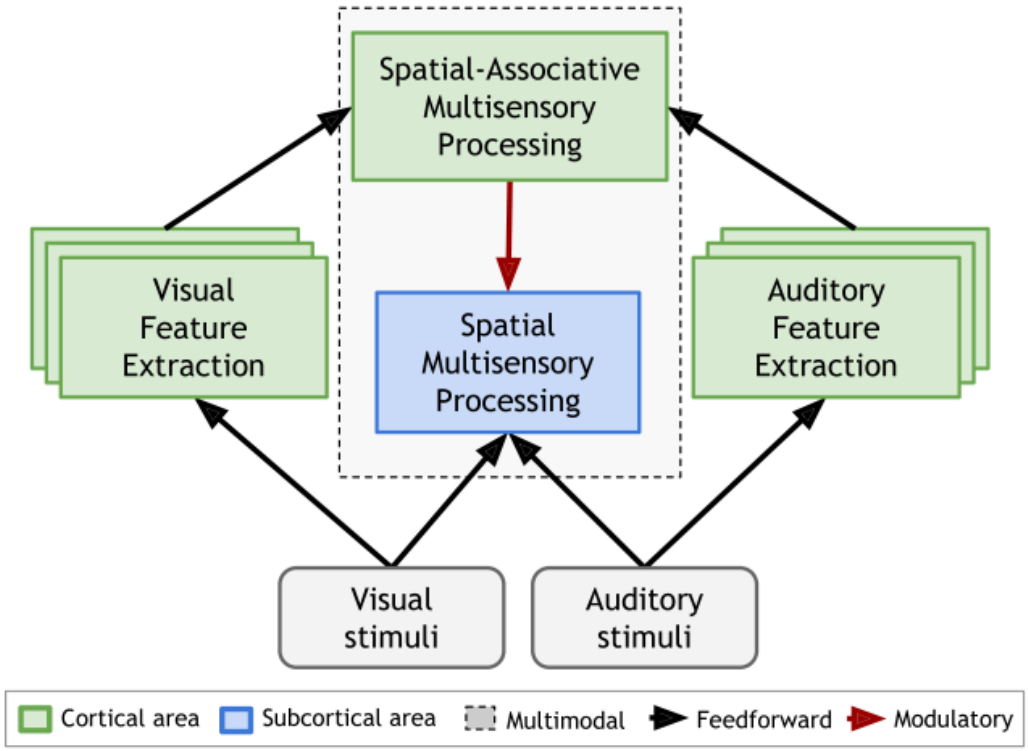

Figure 2 – A flow chart of the structure of multisensory learning [11].

A popular technique to cope with the loss of a sense is called spatial cognitive mapping, commonly known as a mental map or mental palace.

The relevance of the topic of spatial cognitive mapping, MP and sensory substitution is that by gaining basic understanding of how the human brain acquires orientation, navigation and location memory it will be possible to design products that will stimulate the brain in the correct way so that it is easier and simpler to remember their location and identify them correctly. Moreover, it is most important to examine the next step which is called sensory substitution. It is a way to channel the input from one sensory modality into another for instance visual to tactile, visual to auditory, auditory to tactile and so on [12].

This section begins with a brief explanation of what special cognitive mapping is, followed by an introduction to SSD, lastly the focus will fall on the advantages and disadvantages of said devices and what has been discovered can be useful in the development of these products.

Spatial cognitive mapping

Survey knowledge or spatial cognitive mapping is a cross-behavioral structured organization of information or a great mental model of the surroundings which considers the rapport between places, things and people, according to Tolman who first coined the term ‘cognitive map’ [13]. Simply put, it is a mental representation of the location of objects or environmental landmarks relative to one’s own location [14]. The example most commonly used to illustrate this is when a person is asked for directions from point A to point B (in this example B is usually one’s home), the person recreates a mental map filled with street names, turns or landmarks that draw out the route to their house. For sighted people, creating a mental map is hardly a challenge, since the sense most associated is vision, it is different for people with full or partial vision loss.

The literature has studied and examined this process in a variety of scenarios. It started with rats finding strategies to navigate mazes with and without stimuli [13], and is now at a point where neuroscience can study the neural pathways in the developing of a spatial cognitive map in the blind with the help of virtual environment and other SSDs [15, 16]. According to the research conducted in Tel Aviv University by Lahav and Moiduser whose objective was to study the development of spatial cognitive mapping in persons with blindness with the help of a haptic virtual environment, the subjects are more inclined to use the strategy based on linear spatial features. Through the use of compensatory sensorial channels, the subjects were

able to better their performance in spatial orientation. The authors attribute the construction of an accurate mental map to the following criteria: subjects first get acquainted with the space through the use of the multi sensorial virtual environment, methodical study of the same virtual space, and studying the benefits of this exercise relating to the improvement of their touch. This study shows that persons with blindness can effectively create a functional mental map essentially by using sensory substitution [16].

Sensory Substitution

Sensory substitution is the transmission of visual data to visually impaired persons by regularly replacing the visual information with one of the other 4 functioning senses. It is essentially a way for the brain to rearrange and retrain visual information by "translating" into touch, sound, smell and even through electro-tactile signals delivered to the tongue [17, 18]. There has been a longer than expected history in the aiding of this theory through an evolution starting with Braille and arriving at the recent advancements of special devices SSDs that employ algorithms relative to each specific sensory substation coupling (visual to sonar; visual to tactile and so on). S. Maidenbaum, S. Abboud and A. Amedi explore the advantages and disadvantages of SSDs and while the prognosis for the development of these devices is optimistic there are still quite a few important drawbacks [19].

Advantages

It has been shown that regardless of the visual capability in patients the occipital visual cortex (responsible for processing visual information in the brain) does not process only visual information, in spite of the existence of that preference, but also that its function is autonomous from the visual input [20]. The following emerging hypothesis is that each region of the brain can perform its task regardless of how the relevant information was processed and reached, meaning that the visual cortex can in fact identify object location and size, for example, even if that information was input in another cortex [21]. In addition, the visual cortex can undergo a plastic change in order to accomplish even functions which usually occur in the hippocampus (memory) or a combination of lobes (frontal, parietal and temporal lobes which allow for speech and language). All of this leads to some quite positive results in some patients after being trained to use SSDs. One such instance has been documented with a limited number of congenitally blind individuals who, after completing a 70h training using a specific SSD, were able, among other things, to read, and to identify a wide range of things such as objects, buildings, patterns, faces, textures and even depth perception [22, 23].

Disadvantages

Although there has been ample evidence of the advantages of SSDs, these devices have a few rather important downsides contributing to the fact that SSDs have not yet been adopted for common use. The problem has two main aspects, the first of which is that there are problems involving the devices per se. Secondly, there is an issue relating to the limits of overall visual rehabilitation. Elaborating on the first part of the problem, while the use of SSDs for research has been blooming, users of SSDs are usually bound to train themselves in the use of the device in their homes without training from a professional instructor or an instruction manual to follow making them impractical for everyday use [24, 25]. Not to mention the time that the training itself requires whether with or without an instructor. Moreover, even if these devices were more broadly used and the problems minimized, the acquired tasks by the individuals, however useful, do not render them fully independent and the tasks involved are not complex enough to inspire adaptation in ADLs and IADLs such as preparing meals, among others.

Deduction

Despite the many documented motives for optimism and regardless of the exciting results of SSD use, the application of these devices has been mostly limited to research and they are not yet ready for mass use in the blind community. In addition, the results vary from patient to patient and do not seem to be consistent over the variety of diagnoses. Moreover, for optimum results, individuals must undergo some type of training which, especially in cases of self-training, is quite time consuming [22, 24 – 26].

Conclusion

The literature on this topic suggests that if sighted people use visual landmarks to physically or mentally navigate their surroundings, then blind people can use touch or sound landmarks to navigate theirs. The hope is that by adjusting the approach of the aforementioned studies, namely using touch and sound cues, it will be possible to develop a product that will differentiate itself enough that people with visual impairments can easily identify it but also use those cues to successfully map out the contents of their kitchen cabinets. Therefore, design choices as the implementation of textures or embossed surfaces as well as introducing sound as it relates to proper function can be made.

In the first part of this chapter the focus fell on the common causes for visual impairment and the obstacles and limitations that presents on the individual level. Knowing how the individual

perceives their surroundings helped with defining the issues to focus on in the design process. Moreover, understanding the neurological adaptation through sensory substitution and multisensory processing was crucial in identifying possible solutions to recognizing the final product, its function and its contents.

Naturally, visual impairment is not a modern-day affliction and people have been finding ways to get around it for centuries. Codes were adapted for reading and writing, tools and apparatus were crafted for navigation and orientation and what follows is a closer examination throughout history until today of all the various ways human ingenuity has been helping the visually impaired throughout the years.

2.2. Assistive technology for the blind and visually impaired: A history of innovation

From the XIII century until today the invention of products and systems or merely the repurposing and adaptation of existing ones to serve and aid people with vision impairments has been an ongoing trend. At first, it was a movement limited to glasses and low technology vision aids, until the invention of the Braille code which to this day continues to be an inspiration for the latest technological advancements in the realm of vision impairment. A summary of this evolution will be presented in the end of this chapter, tracing this progression and ending in an analysis of current trends justifying the need for a wider range and richer diversity in the products available for the people with visual impairments. The motivation behind this topic of research is to study the reasons for the developments and the solutions previously implemented in order to surmise the best resolutions as well as the limitations they may have. The conclusion of this topic will contribute to and complete the design decisions which will be employed in the development of this project.

2.2.1. Evolution from XIII to present day

As most human conditions, blindness and visual impairment have been present for millennia in myths, legends, and real historical events. For these reasons many people throughout history have attempted to better the life of the people affected. As far back as documented events go, the first development was in 1266 when, in his Opus Majus, Friar Roger Bacon bases the usage of corrective lenses on scientific principles [27]. In the following centuries there is little to no documented innovation until the year 1821 when Louis Braille meets the soldier behind the “night writing” code, Barbier, which could be used by soldiers to communicate at night.

As shown in figure 3, Barbier's code was formed of 12 dots, Braille simplified it to 6 dots thus making it easier to learn and to adapt for the blind community, creating the Braille code [28]. This includes numbers as well as letters, of course, and to signal the change the numbers are written using a number sign preceding the first 9 letters of the alphabet.

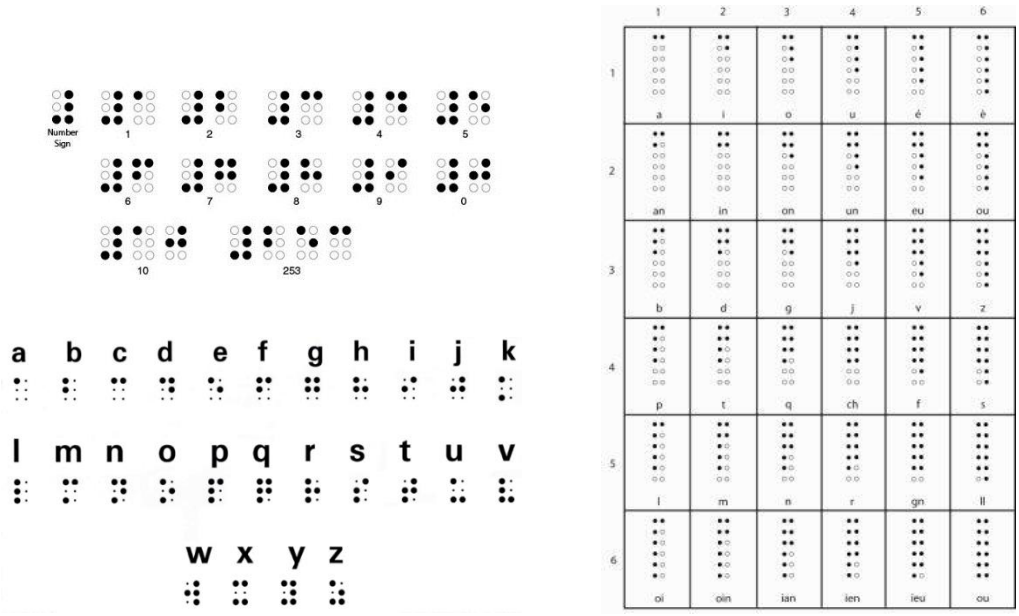

Figure 3 – Braille code (left) was inspired by the night code (right) and largely simplified [28].

Nearing the end of the 19th century, William Perkins receives a patent for his Writing machine for the blind [29]. This leads to further developments in the mid-20th century with the automatization of text-to-braille converters. One result of these advancements is the Optacon [30]. Another similar line of development started in the 1890's with the Elektroftalm which first endeavored to transform visual images into sound and some six decades later attempted to do a visual-tactile conversion. The device converts the electrical signal of the photocell into sound waves; however, the device was very large and heavy as seen in figure 4 [31]. These works paved the way for the pioneering work in the application of sensory substitution for research by Paul Bach-y-Rita focusing on visual to tactile conversion. Probably one of his most noticeable works is called the "Tactile Vision Sensory Substitution" which allowed users to identify big letters and perform some basic "eye"-to-hand coordination such as identifying a ball, perceiving its movement in space and catching it [32].

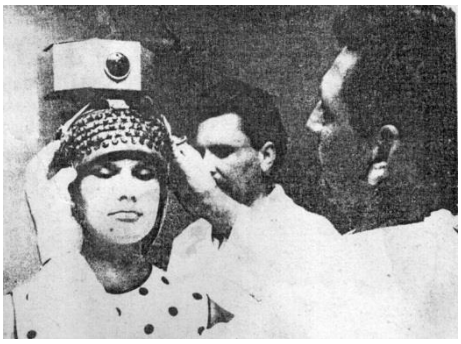

Figure 4 – Elektroftalm device [33].

2.2.2. Latest innovations: development stages and products on the market

In this section, the focus will fall on exploring some of the latest developments in accessibility and improving quality of life for the blind and visually impaired. It has been concluded that when it comes to cooking three areas are key. The reasoning behind this deduction is as follows: after one decides what one wants to cook one steps into one's kitchen where one must orient oneself and locate all the equipment. Once that is done, one must identify which equipment is relevant and which ingredients are necessary. Finally, when all of the above is accomplished one can begin to cook. Following is a presentation of some examples of devices in all three areas and the mechanisms they use starting with orientation aides, moving onward to communication and education and finally taking a look at one of the most complete sets for cooking blind the author was able to find.

Orientation aids

Ducere technologies' Lechal shoe sole, is a sole that fits in any shoe and is connected to your mobile device via Bluetooth to ensure function even when offline (figure 5). The insole vibrates in the shoe to indicate where to turn and when. For example, a vibration in the left shoe will occur when a right turn is expected and it will vibrate more and more as the turn approaches. The insoles have a battery that lasts up to 15 days. The insoles function as a Fitbit as well, keeping track of step count, calories burnt and distance travelled [34].

Figure 5 – Lechal insoles using vibrations and GPS to guide the user to their final destination[34].

Communication and education:

FingerReader is a ring-like device that functions with a camera. As observed in figure 6 the user puts the device on the index finger and follows the printed text, much as one would do intuitively when learning to read so to not lose track. The device scans the text and through the help of an algorithm reads it out loud to the user. In its form as of 2015, the device cannot function without a connection to a computer [35, 36].

Figure 6 – FingerReader device [35].

Screen readers:

Web accessibility ensures full access to all information available on the internet for people with any and all disabilities that may impede their access, as part of the Universal Declaration of Human Rights. Article 19 of the document written in 1948, declares the inclusion of pursuing, attaining and conveying information and ideas via all media and without limitation as part of the fundamental right of freedom of expression [37]. Key players in this are software

programes called screen readers like JAWS®, non-visual desktop access whose purpose is to facilitate visually impaired persons in accessing information by providing a speech synthesizer or a Braille display so they could browse online for news, books, music and entertainment and also shop [38, 39].

Cooking:

Developed by then student of the National University of Singapore Kevin Chaim Folks is a line of kitchen equipment developed specifically for use by people with visual impairments based on tactile cues and sensory feedback [40]. The project of this thesis is based on Chaim's project as some important steps were missing. Noticeably the lack of any component involving seasoning and as it is well established the seasoning is one of the most important components of a delicious meal, just as important as the cutting of the food, cook temperature and cook time, as shown in figures 7 and 8. Therefore, Folks will serve as a guideline for this work following the simplistic and low-technological approach of the designer creating a practical, easy to use and affordable tool to improve the quality of life of individuals with visual impairments, blind and partially sighted.

Figure 7 – From left to right: adjustable lid with safe escape for steam, various diameter size stove top base, liquid level indicator from Folks kitchen equipment.

Figure 8 – From left to right: protective knife and cutting board, cutting board accessory for easy transfer of cut products to bowls or pans.

As of yet it has become evident in which circumstances vibration, sound, the Braille code and other atypical methods can be used when it comes to overcoming the limitations of sight loss in the ADL as it relates to the topic of cooking.

2.2.3. Cooking blind – combined testimonials from blind chefs

It is well known that even in the best of circumstances the kitchen is an area of the house prone to accidents and mishaps and it is only fair to imagine that it becomes even more challenging when sight is no longer a sense one can rely on. The Internet is full of blogs and websites by private individuals or organizations for the blind covering all sorts of tips and tricks to navigate everyday activities as a blind or a visually impaired person. In the objective to collect as many coping mechanisms to bypass these difficulties the following research begins by categorizing the data found.

Internet tips

- Organization is vital

  As with all spaces where a visually impaired person spends their time, the kitchen is a meticulously organized area. After use everything must be put in its place in order to avoid mix ups with the ingredients [41 – 43]. As Tom Lewis, from the Monachyle Mhor Hotel in Perthshire, Scotland said “You have to put ingredients back in the same place each time,[...]In mum's kitchen, everything was as it should be - hazelnuts in the top left of the pantry, sugar bottom right.” [41]

- Cutting and chopping

  Most of the advice here starts with the focus on visually impaired individuals saying that the chopping board must be in a contrasting color to the food and adding extra lighting on the cutting area as exemplified in figure 9 [44]. The contrast will work only for people who are able to differentiate between colors or at the least between light and dark. While it might work for some it does not work for those who are blind, furthermore though the contrast helps with giving a vague scope on where the food is on the board, it does not provide any assistance when it comes to cutting the food safely and with mild precision.

Figure 9 – Low vision double face cutting board by MaxiAids [45].

- Measuring and Pouring

Almost all of the sources analyzed suggest to use all measuring tools above a baking tray or cake tray or a similar container to help with cleaning up in case of spillage. This shows that even when using braille measuring cups or spoons the user still runs the risk of spilling or overloading which means that even though these tools are meant to be easy to read, they are not so easy to use seamlessly. Among the commonly mentioned advice is to use light colored products for dark ingredients and dark colored products for light ingredients suggesting the necessity to buy two sets of the same products as exemplified in figure 10. It is possible to conclude then, that the products currently available on the market, for the large part, are not full proof and there is still to be desired [41, 43, 46].

Figure 10 – On the right: Braille measuring spoons in white. On the left: the same spoons in blue [47].

As for pouring there are many liquid indicators, however the most popular one is the Sensa Cup Level Indicator MK111 as shown in figure 11. The user hangs the product off the rim of the cup, the product self-adjusts to the size of the container. The user begins pouring the liquid in the container and when the liquid fills up the container to 15

millimeters off the bottom a sound is emitted, the sounds go off again when the liquid reaches 15 millimeters from the rim of the container [48].

Figure 11 – Sensa Cup Level Indicator MK111 by Cobolt Systems LTD indicates the level of liquid in the cup by making a sound in the beginning of pouring and at the end – when the liquid reaches 1.5cm below the rim of the container.

Additionally, figure 12 shows an adjustable measuring cup by OXO [49], which appears to be simple to use, and unlike other measuring tools, does not come with a six piece or ten-piece set. Admittedly, it is not a product for the visually impaired, however it does falls short on a few aspects. For instance, if one were to simply change the labels to Braille code, this cup will still require some time of pouring ingredients into it and risking spillage, as well as having to "shave off" any excess with a spatula or a knife thus certainly spilling the ingredients.

Figure 12 – Adjustable measuring cup by OXO [49].

- Labelling and identification

Sue Pallet of The Accessible Friends Network says "Packets of dried goods [...]can be emptied into differently shaped and sized sealable plastic storage boxes, the name of what they contain written on the front of each box for easy identification. Apply a Braille sticky label [..] or attach an elastic band to them." [46].When it comes to identifying the items in the kitchen most blind or visually impaired users rely on memory, but there are specific areas where simple memory is not enough. While using what is essentially spatial mapping can be very useful for items which are big or used often, spice racks or pantries often have large amounts of different items one does not use on a daily basis. When the time arises to use one of those items it could be challenging to find the correct one. This is why the blind or visually impaired often rely on audio labels. The most popular of these devices is called a PENfriend. This device operates on batteries, uses magnetic waves and comes with a large number of bright color labels. The user records the label name on the pen which pairs recording to label. After the user has labelled all the items, all that is left to do is place the pen on the bright label and listen to the recording [50]. The problem with devices like this is that it could take time to find the item the user is looking for, especially on a spice rack or a pantry. It is also worth mentioning that the price of the PENfriend3 is

79.99£ as of 20, September, 2019 [51]. A low-tech version of the PENfriend is using creative everyday items to label your ingredients, like different size and shape containers, elastic bands with different textures, or braille printed labels.

- Rely on other senses i.e. multisensory substitution

When cooking the most common advice found is to listen to the sounds the food makes while cooking, paying attention to the smell or simply touching and/or tasting. One important suggestion came for ched Christine Ha who is the first blind contestant on MasterChef USA and winner of season 3 of the popular cooking show. Ha was contacted by the author and provided the idea for the oil dispenser. In her words "Think of bartenders who use stoppers and spouts on their spirit bottles when working to know exactly how many ounces they're pouring by the number of seconds they're counting." She herself however mentioned that her measurements are rarely accurate stating "my measurement for oil in a pan when sautéing is never exact" The obvious problem with these techniques is that the individual needs to have a lot of practice in the kitchen in order to discern based on time how much oil is in the pan or based on smell when the garlic is fried just right. The issues with this hands-on approach seem to accumulate the more it is analyzed i.e. if relying on touch the person might burn themselves, if relying on sound the issue is very similar to the smell example, finally if relying on taste the person may only be able to correct the seasoning but could not always identify if the food is done [41 – 44].

- Common sense strategies

When in the kitchen it is considered common sense not to touch the stove top, wear protective gear like an apron and mittens, not wear long, flowy sleeved shirts above the stove top especially if it is a gas one and so on. Of course, this advice applies also to people with visual impairment. Other common tips include using mittens with longer sleeves, turning off the oven and the stove top before taking the food out, making sure the racks in the oven are on the proper level before turning on the oven among others [42 – 44, 46].

Based on this first part, it is possible to deduce some of the criteria the products must have. They must be available in slightly different shapes for easier identification of the spices and condiments, they should make spilling a lot more difficult than the currently available products, they should be adjustable to differently shaped and sized containers, they should be

easy to install, take off and clean and finally they should be budget friendly and not create other danger hazards.

2.3.Summary

This chapter began by explaining what MP is and why it is relevant to understand it. This insight led to the concepts of spatial cognitive mapping, sensory substitution and SSD. It is of value to understand the neuroscience behind the adaptation to the loss of arguably the most important of all five senses. Subsequently, it was deemed necessary to examine the history of tools and gadgets which have been developed to aid persons with blindness over the past centuries up until today. Finally, the focus fell on the more practical matters of cooking blind, as testimonials were gathered from blind chefs and cooks as well as consulted self-help and self-improvement websites and forums on the topic of cooking blind.

3. Design development: hypothesis and mechanisms

After the contextualization has been made on visual impairment and its implication to the individual on all levels, and a study on multisensory compensatory neurological mechanisms was completed, it was then possible to move on and analyze the current state of the market for assisted technology The subsequent phase of this work was to begin the design process. As was previously introduced in Chapter 1 the presentation of the requirements and hypotheses for both products complete with hypothesis generating, analogical inspirations and theoretical basis. First, a look at the presentation of the requirements for the oil dispenser complete with an analysis of the most probable bottles this product will complement.

Following is the same analysis for the spice dispenser, again with a consideration of the products widely available in Portugal.

3.1.Requirements and hypothesis

Generally, both the oil and the spice dispenser share some of the basic requirements. They should both be:

- standardized accessories which could easily be inserted on the customers favorite brand of oil or most commonly found spice jars. (For all intents and purposes, the standard that will be used will be based on the Portuguese food and beverage market.)
- inserted into the product packaging with a minimum amount of physical effort
- inserted into the product packaging with a minimum amount of legibility[1] difficulty.
- Ease of use and full proof dosing

In order to transform the aforementioned customer needs and more into functional requirements and design parameters axiomatic design analysis will be applied. Axiomatic design is a scientific way of viewing design providing a consistent set of tools to assess each design decision by dividing the process in 4 basic domains. According to Suh [52] first, one must determine the customer needs (customer domain) or what is the benefit that the customer seeks. This is followed by the functional requirements (functional domain) which is the definition of requirements that completely characterize the objectives for a specific need. The functional requirements must provides functions and not solutions. The solutions are defined in the design parameters (physical domain) and they must satisfy the previously established requirements. Finally, the process variables (process domain) is meant to identify the elements that characterize and satisfy the design parameters [52]. This analysis will be applied on both products bellow.

Oil dispenser:

By implementing the axiomatic design analysis for an overall parameter definition it was determined that the oil dispenser (see Table 2) must be equipped with a mechanism to control the flow i.e. to dispense a fixed dose, must have one or more clearly signalized buttons so as to be obvious how to use the product, must be a small size to facilitate storage, must be of a

[1] In the 2004 book Emotional Design, D. Norman explains that one of the crucial elements of behavioral emotional response to a product is its legibility meaning how easy is it for the user to understand what the product does and how. This is also referred to as understandability [60].

waterproof material which is easily moldable and with a slick minimal design so as to be both cheap and easy to clean, must be textured and of high contrast to facilitate differentiation between containers, must be of a size which fits the most common packages.

Table 2 – Axiomatic design analysis for oil dispenser.

Customer domain	Functional domain	Physical domain	Process domain
Dosing	Controlled flow	Mechanism	whistle
Useability	Poka-Yoke	Basic design	No big alterations*
Storage	Small	Measurments	No big deviation *
Cheap	Material+low tech	Minimal design+materials	Plastic/silicon
Clean	Water proof	Material+smooth lines	Plastic/silicon
Differentiate	Tactile/visual details	Textures + high contrast	Geometry + colors
Adaptable	Fit common brands	Market standard measurments	Fit standard bottles
			*From standard spout

As previously stated, the brands used for the purposes of this work are olive oil Gallo and sunflower oil Fula. Figure 13 show reference images of the standard 1L bottles of both products and the pouring cap they come with already. The attachments both products come with are quite different. The main issue these attachments have is that while they control the flow of the liquid, they do not communicate how much liquid has been expelled, which is the problem this work focuses on. As shown in figure 13, the olive oil attachment is more complex and in order to remove it one must use a thin, strong object such as a butter knife. The procedure to remove it requires precision and attention. The geometry of the neck of the bottle and the attachment is quite similar and if the surface is greasy from the oil, differentiating between the glass bottle and plastic attachment through touch could be a difficult task. Precise and safe work to remove the latter might be challenging if the vision is diminished. However, it is easier to remove when covered with a kitchen cloth or paper towel. What is needed then is a strong grip.

Figure 13 – Reference image of the standard 1L bottles of olive oil Gallo (left) and sunflower oil Fula (right) [53, 54]. The images on the extremes were taken by the author.

On the other hand, the attachment on the sunflower oil bottle, while still quite difficult to remove, leaves room for the insertion of a separate attachment which can alert to the quantity of liquid which has been poured. As seen in figure 14 the attachment on the bottle of olive oil has a much more restrained pour which might leave the visually impaired unaware of the amount of liquid that has already been discharged and unaware of the amount of time necessary to discharge the amount required by the recipe or personal taste. In the same figure on the right, the opposite occurs with the attachment on the bottle of sunflower oil where regardless of the attachment the liquid pours out at a much higher rate.

Figure 14 – Images taken by the author illustrating the difference in flow between the two attachments.

Proposal:

The proposal presented here is but one solution and it was chosen based on the axiomatic design, specifically for being small, low technology, easy for manufacturing amongst others. Build on the already existing solutions: specifically, modify the regular pour spout for distilled alcohol so it can also indicate when the bottle is almost empty using sound. Both olive oil and

cooking oil share the property of making no tangible sound when being poured into a container due to their high viscosity. This property is highlighted when the standard bottles have attachments to control the flow thereby preventing any likelihood- of splashing sounds. Therefore, the initial idea was to adapt a whistle mechanism into the spout, modify the air tube to enhance pressure of air flow and make a sound when too much air enters the bottle, indicating that there is less liquid to hinder the airflow. Following some deliberation and research the direction of the investigative process led to the Moo Box as seen in figure 15.

Figure 15 – The Moo Box or Cow Can is a toy popularized in the the XXth century which when turned upside down and then back creates a moo-like sound.

The reason for the shift from the regular whistle to the toy is that the toy works without external blowing but rather by using basic airflow principles. The box mechanism constitutes of a weight with air channels, a sealed rubber and flat plaque. When the toy is turned upside down, the weight pulls the rubber but not the plaque, thus when turning it right side up again an air bubble is created in the rubber and by having the wight press down, the pressure of the air flowing through the channel augments entering the whistle at a sufficient pressure level to produce the sound. The theory is that by recreating and adapting this mechanism it will be possible to incorporate a quantity indicator in the dispenser. Hypothetically, by using Bernoulli's law of conservation of energy by altering the diameter of the tube and placing a whistle at the end of the smaller diameter, the velocity of the airflow will be enough to create a sound that will indicate that liquid is existing the chamber. Moreover, by controlling just how much air goes into the bottle and taking into consideration the viscosity of the oil, it will be possible to control the amount of liquid exiting. As to alerting the individual to the decreasing amount of oil in the bottle, it is anticipated that as the liquid reduces, the airflow

will reduce respectively thus will not create enough resistance and the sound will get softer and lower.

During the prototype manufacturing the whistles available to the author became damaged, this led the author to look for other similar whistles which were found in doggy chew-toys. The size and shape varied slightly to the whistle in the Moo toy, however, the whistles share the same mechanism which was determined to be the most important feature for the purpose of this work. The variations in size and shape are easily altered in the 3D modelling process and will prove to be irrelevant to the prototype manufacturing.

Spice dispenser:

Using the axiomatic design analysis as a general guideline it was determined that the spice dispenser (see Table 3) must be of standard size to adapt to the market standard for spice containers, must include a dependable mechanism to ensure steady and controlled flow of spice i.e. dose, must be of minimal design with smooth lines and water resistant for easy cleaning and risk free use, food safe materials and/or finishes, must come in a variety of high contrast and textured materials to facilitate differentiation between spices and containers and finally must be a poka-yoke design as to not create any added difficulty to use which will be incorporated by the implementation of a simple, obvious button.

Table 3 – Axiomatic design analysis for spice dispenser.

Customer domain	Functional domain	Physical domain	Process domain
Dosing	Controlled flow	Mechanism	Spring
Useability	Poka-Yoke	Obvious design	Button
Storage	Small	Measurments	Fits standard jar
Cheap	Material+low tech	Minimal design+materials	Plastic
Clean	Water proof	Material+smooth lines	Plastic
Differentiate	Tactile/visual details	Textures + high contrast	Emboss figures + indicator elements
Adaptable	Fit common brands	Market standard measurments	Fit standard jar
Safe	Risk free use	Foodsafe materials/finishes	Kitchen grade plastic

Having defined the parameters within which to concentrate the development of this design it is now necessary to analyze the context in which to work. Two types of spice packaging are considered in this work. The first is spices in a jar (regardless of brand as for the purpose of

this work they are considered the same) with two settings, on the left of figures 16 and 17 is the setting for larger amounts and on the right – for smaller amounts.

Figure 16 – Spice jar for powder with two openings, on the left - for larger quantities and on the right- for smaller. (Images taken by the author)

Figure 17 – Spice jar for dried leaves with two openings, on the left - for larger quantities and on the right- for smaller. (Images taken by the author)

Knowing that seasonings come in various forms in various forms, for example powdered, dried leaves and grain was an aspect that was considered, however at this junction it is irrelevant as the observations were the same across all forms. Several issues were discovered in the case of the jar. Most notable was the fact that regardless of the grain or consistency, the openings in the lid of all jars fall in the extremes of spice dispensing i.e. either they dispense too much with little to no control from the individual or they dispense too little, as shown in figures 19 and 20. Another occurrence is that while cooking the steam usually reacts with the spice (all forms) and blocks the holes. In Portugal spices and herbs are often sold in plastic bags as seen in figure 18 so the consumer can refill their own jars and containers.

Figure 18 – Example of spice sold in a plastic bag [55].

The second type of packaging is the plastic bag shown in figure 18 by Margão [55], here as well the brand is chosen merely for its popularity and is irrelevant in the discussion at hand as most brands use plastic bags with the same functionality.

Figure 19 – Three images taken by the author. From left to right: too much flow of powder in the large setting: uneven flow and no flow (the latter sometimes occurs even when shaken).

In figures 19 and 20 on the other hand it is shown what generally happens when the consumer decided to purchase herbs and spices that come already in a container with a dispenser. Figure 19 illustrates the three outcomes when using the built-in lid with a powdered spice like black pepper where either too much spice is released, not enough or nothing all together. The pictures were taken using the larger hole setting making the outcome even more surprising, similar were the results using the smaller holes setting and the author believed it not necessary to include those pictures so as not to be repetitive (figure 20).

Figure 20 – Two images taken by the author. On the left the jar dispenses the dried leaves at a rate which is very difficult to control using the larger hole setting and, on the right, – almost no dried leaves are expelled of the container using the small hole setting, even when shaken.

Proposal:

The proposal presented here is one possibility which was selected based on the axiomatic design, for mostly the same reasons as the oil dispenser and a few specific to this product e.g. customization, and the combining of 3 functions into one motion. In the case of the spice dispenser, the proposal was to modify the standard measurement lid most spice jars purchased in Portugal have, by incorporating the valve to the bicycle bell button (see figure 21) with an agitating part. The reason for the bicycle bell is the spring back mechanism it has. This is important in order to ensure that the user won't be able to press on it too long, keeping the valve open for too long and risking that a larger amount of spice will come out than the desired amount. The reasons why the agitating part will be connected to the button is that by pressing the button the potentially clumped up spice powder will get loose and come out of the dispenser easily without requiring additional agitation or invasive mixing. It was also concluded that naming the exact amount of dispensed spices, at this stage, is overshadowed by the requirement of always dispensing the same amount, no matter what that is.

Figure 21 – Reference image of the bicycle bell model used as inspiration.

3.2.From customer needs to functionality

After the definition of the requirements was completed, proceeding forward is an examination of the possible material/texture combinations which could be used in order to give a variety of possible associations with the spices. The main focus for this material selection is for the button and the top part of the dispenser as those will be the two surfaces most touched by the user, therefore main elements for differentiation. Table 4 shows a selection of materials that can be used for the production of these products based on functionality and properties and the possible texture finishes for each material. For example, use a natural wood finish on the end of the lever of the jar to convey nature, or the most natural form of spices i.e. dried leaves; because of its grainy texture, not sanded cork can be associated with grains or crystals and so forth. In order to transmit this idea some illustrative images have been combined in the figures below.

Table 4 – The available combinations of textures within the materials are used here to illustrate the similar adjectives used to describe the material and various types of spices.

Textures / Materials, Finishes	rough, harsh	Glossy	matte	cold	warm	dry	wet	elastic, rubbery	hard
wood, natural			X		X	X			X
cork	X		X		X	X		X	
rubber		X			X		X	X	
plastic		X	X		X				X
metal		X	X	X		X	X		
glass		X	X	X			X		X
ceramics		X	X	X		X	X		X
stone	X		X	X		X			X

What can be concluded from the analysis in Table 4 is that through the choice of the material in the final design, the final product will use the notions discussed in 2.1. The workings of MP and SSD are simply applied in the design as to make the product accessible for the user. By using materials with textures which remind the user of the seasoning in the container it will be easy to identify the type of seasoning the user is holding. Although the material alone cannot sufficiently differentiate between the various spices (wood is dried leaves, but what), then the following step would be to introduce patterns to be able to specify even better which herb it is. This is where a further study on the button part of the design is needed.

- Wood: Matte, warm, dry = dried herbs
- Cork: Rough, matte, warm, dry = crystals (salt, sugar)
- Alluminium: Matte, cold, dry = powder (e.g. paprika, curry)

As seen below in figures 22, 23, 24 the resemblance in texture between the various materials and the various types of seasonings. For example, in figure 22, the parallels between the grain and texture of the smoked oak are visually and texturally almost identical to the dried basil leaves, as of course they are both flora, that is to be expected. In figure 23, the same is observable. The likeness of the cork grains is reminiscent of the salt crystals. On the other hand, the sandy texture of the aluminium, especially brushed or blasted, is evocative of the sandy, dry texture of the powdered turmeric as illustrated in figure 24.

Furthermore, the button provides some additional opportunities for meeting customer requirements as well as being the point of focus for added value to the user experience.

Figure 22 – Smoked oak on the left (photographed by author) and dried basil leaves on the right [56].

Figure 23 – Cork on the left (photographed by author) Himalayan salt crystals on the right [57].

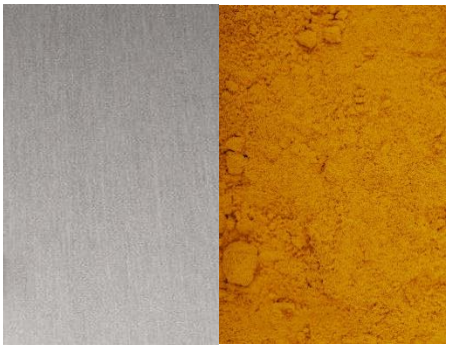

Figure 24 – Brushed aluminium on the left [58] and turmeric powder on the right [59].

3.3. Summary

This stage of the design process began with a transition between the all the information gathered from the fields of neuroscience and research and development in assistive technologies i.e. MP, spatial cognitive mapping and SSDs and an analysis of the market today. This knowledge was used as a basis for the analysis of the standard packaging of oil, herbs and spices in Portugal. The assessment focused on the purely geometric aspects of these packages as shapes and dimensions, then shifted toward use and a positive-negative evaluation of the functionality of the dispenser attachments the packages come with, if any.

This assessment led to hypothetical solutions to the encountered short-comings as well as an idea generating process which included taking inspiration from a few unexpected sources such as classic toys.

4. Implementations of hypotheses

This work has, until this chapter, contextualized the persons with visual impairment in relation to both persons with disabilities and persons without, thus introducing the motivation and objective of this work.

A scientific exploration of the popular phrase “when you lose one sense, the others get heightened” was undergone in the beginning of chapter 2. Evidently, ample proof the truthfulness of this phrase was presented through an inquiry in the field of neuroscience, whose focus was multisensory processing and SSD. Naturally, the matter of devices was

further investigated through an overview of the evolution of assistive technologies throughout the last centuries leading to the latest innovations in the area of assistive technology for the blind. Chapter 2 concluded with testimonials about cooking blind from blind or visually impaired chefs which were used as the base for the development process started in the chapter 3.

Chapter 3 implemented most of the information gathered up until then as it related to ease, simplicity and reliability in dispensing the desired quantities of oil, herbs and spices while cooking blind. The hypothesized solutions were based on a blend of the mechanics of MP, successful experiments with SSD and the testimonials from visually impaired chefs. Two proposals were presented, one for a universal oil dispenser which alerts the user to the quantity of oil left in the bottle and one for a universal spice and herb dispenser which always lets out a standard amount of spice by insuring both no clumping and semi-mechanical open-close mechanism.

In this chapter is a look at the implementations of these hypotheses by presenting the development stages of the proof-of-concept prototypes.

4.1. Implementation experiments on the oil dispenser

First, a summary of the identified requirements with the oil dispenser is necessary:

- standardized accessories -fitting for standard bottles of common Portuguese brands of olive and sunflower oil
- little to no physical effort required to insert product onto bottle
- little to no difficulty in understanding how the product works
- easy to use and reliable dosing

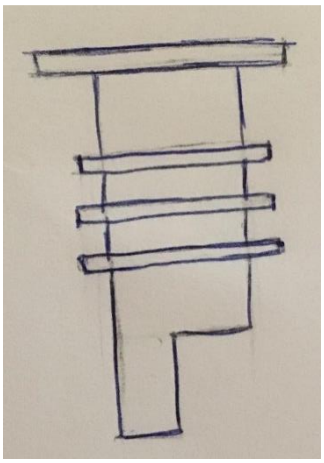

Figure 25 – Sketch of bottom part of pour spout.

When it came to begin sketching the elements it became evident that when it relates to the design of this product few changes will be made to the market standard. To evidence this, figure 25 shows the part of the spout that is inserted into the bottle. Fairly standard, it is characterized by 4 disks: three on the bottom to block any leackage and provide good fit; and one the very top to sit on the rim of the neck of the bottle. Inside it will have the standard 2 tubes for air and liquid.

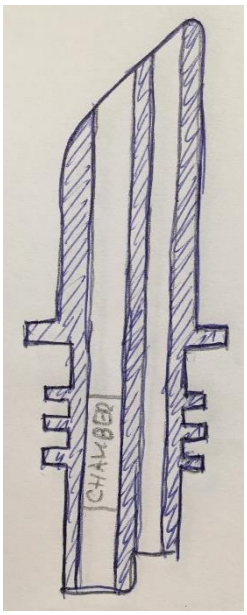

Figure 26 – Sketches of section views of pour spout.

It soon became clear that the only noticeable difference between standard pour spouts and this one will be surely on the inside. It was conceptualized to have some type of extra space to

account for the sound mechanism as seen in the tubes on the left in both sketches in figure 26. The other differences will be purely aesthetic and ergonomic ones.

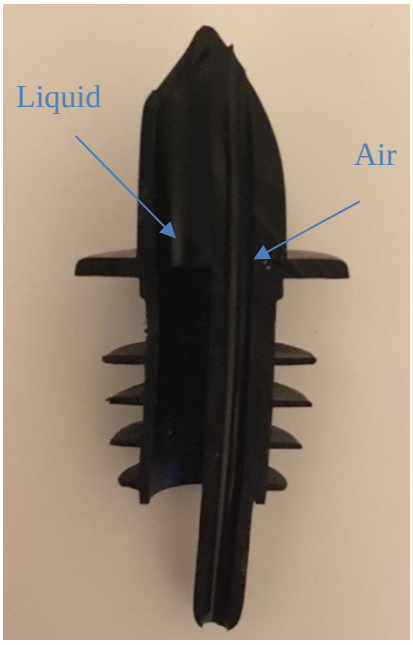

Figure 27 – Section of a standard liquor pour spout with a hole for the liquid to exit on the left and an and a hole for the air to enter on the right.

The first experimented solution was based on the liquor pour spout combined with a whistle. The available whistle was too big to fit into the store-bought spouts, so an original prototype was fashioned using mostly household objects and utensils. The prototype is based on the classic pour spout following the same architecture as seen in figure 27, where there is one tube for the air to go into the bottle allowing the liquid to steadily flow out of the second tube.

The elements that were used for the making of this first and very basic prototype are as follows:

- The whistle extracted from the Moo box (see figure 28)
- Aluminium foil
- A metal straw
- Hot glue
- Silicone cap

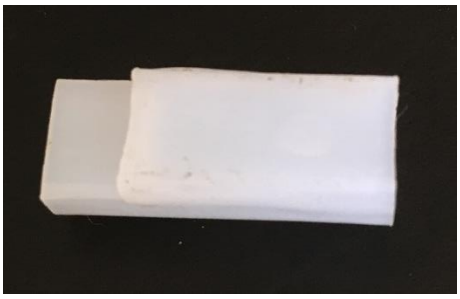

Figure 28 – Whistle extracted from Moo Toy.

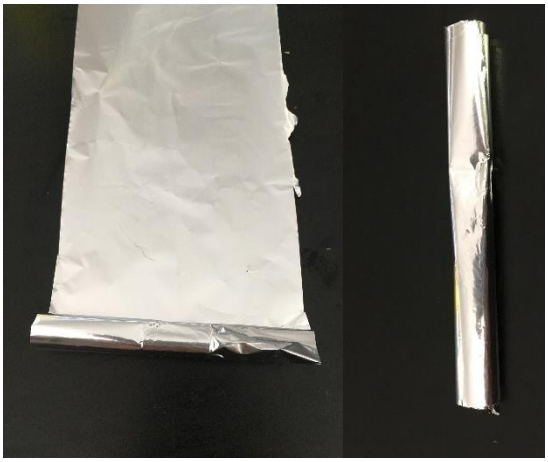

Figure 29 – The whistle was wrapped in aluminium foil to simulate a tube for airflow.

The whistle (figures 28 and 29) was carefully wrapped in aluminium foil to make a tube around it. The resulting "whistle straw" was then glued to the metal straw using hot glue, not just for the convenience but also for the air-free binding it provided i.e. the hot glue created a solid union between the elements which did not allow for air or liquid to escape (see figure 30).

Figure 30 – The wrapped whistle was glued using a hot glue gun to a metal straw.

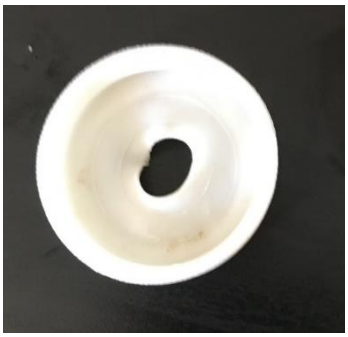

Figure 31 – A silicone cap was used as a fixing agent for the neck of the bottle.

The silicone cap (figure 31) proved very efficient as it not only provided further isolation between the straws and the neck of the bottle (figure 32) but also fit perfectly around the neck of a 0,5L glass bottle. The first experiment of the device showed promising results. The whistle did in fact make a noise while the liquid was pouring and the noise became quieter and quieter as the bottle emptied. However, in this first attempt, the mistake was putting the whistle below the the tube for the liquid instead of above, which resulted in liquid going into the wrong pipe. Another problem was the tube for the air in the prototype was larger than the tube for the liquid, which is the exact opposite in standard pour spout, this in combination with the poor positioning resulted in liquid going into the tube for the air as the bottle was being emptied thus impeding the release of any noise from the whistle.

Figure 32 – The combination of all the elements result in the first finished prototype.

Considering these findings, it was determined that proof of concept was established. The development of the prototype continued in the same direction by modelling a 3d model of the dispenser and 3d printing it. The mistakes from the very first attempt were rectified moving

forward. This process was lengthy seen as the method used for the adjustment of the measurements was trial and error. Following is a photographic presentation of the various design evolution stages with explanation and analysis.

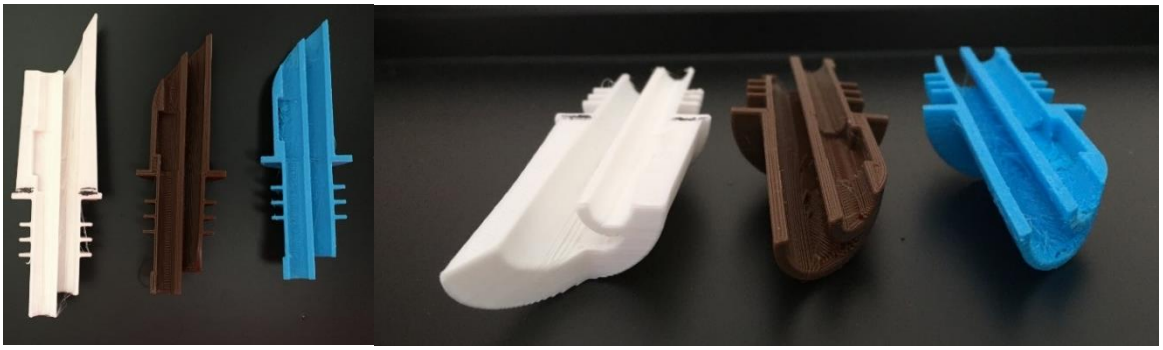

Figure 33 – From left to right: first and second prototype made in plastic, third is in gel plastic. Section top view on the right and section front view on the left.

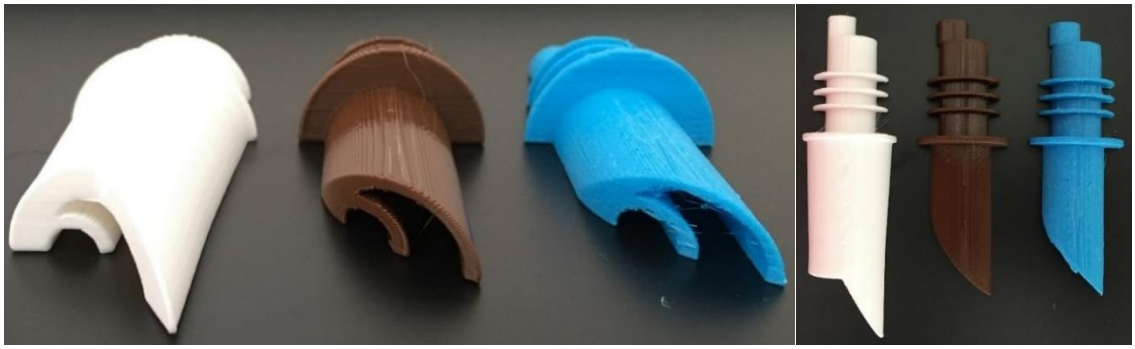

Figure 34 – From left to right: first and second prototype made in plastic, third is in gel plastic.

The prototype development is shown in figures 33 and 34 where from left to right on both images the progression of the initial shape as well as material selection can be seen. The pieces in white and brown were printed in standard 3D printer plastic while the blue is in gel plastic. The switch in the material was the result of the lower part of the pour spout having to enter in the neck of the bottle which requires a softer silicone-like material. In this initial stage the author wanted to study the geometry and the functionality of the primary features while evaluating tolerances and performance of the 3D printer. The purpose was to determine how to optimize the design while optimizing the printed results. As seen in the images above the very first prototype in white was quite large and thick because of the authors unfamiliarity with the quality and precision of the 3D printing process. The second prototype in brown was considerably slimer and slicker in design however it was necessary to print it again but in gel

plastic in order to observe the performance of this filament within the manufacturing process (prototype in blue).

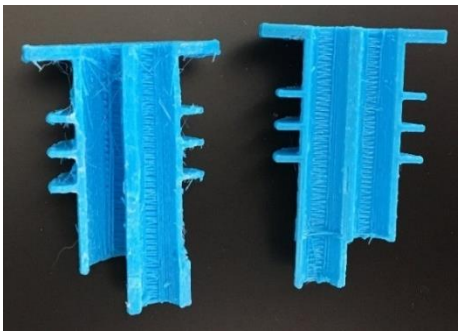

Figure 35 – Cross section of lower part of the pour spout.
Left: initial design, right: modified design.

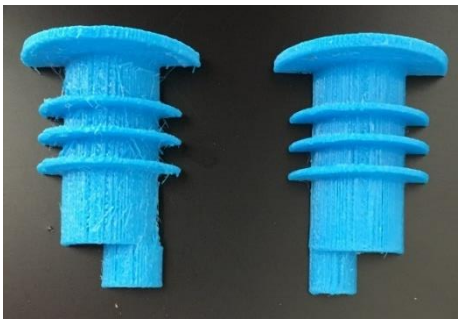

Figure 36 – Cross section of lower part of the pour spout.
Left: initial design, right: modified design.

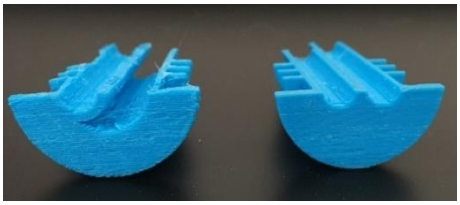

Figure 37 – Cross section of lower part of the pour spout.
Left: initial design, right: modified design.

It was decided to divide the prototype in two halves – upper and lower. The reasoning behind this decision is that by doing so each half can be printed in what is believed to be the most adequate filament for its purpose where the upper half (the one outside the bottle) will be solid and the lower half (the one that is inserted in the bottle) is in gel filament to ensure easier insertion and blocking any possible spillage. In figures 35 through 37 is a cross section examination of the lower half of the pour spout. In each figure on the left is the original design and, on the right, the improved version. As easily observed, the differences include a change

in shape and diameters of the two tubes as well as an improvement of the printing quality. It was hoped that these improvements would be sufficient to manufacture an air tight prototype, however as explained below it was not the case.

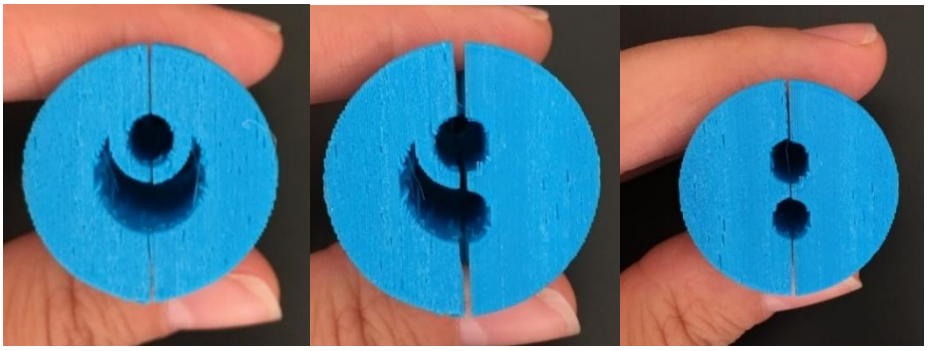

Figure 38 – Left to right: initial cross section, initial vs. final, final cross section.

In figure 38 is the evolution of the cross section of the lower part of pour spout. As seen on the left, the first prototype followed the original design of the upper half which upon further examination was found to be too disproportionate. The tube for the liquid is much larger than the one for the air to come through, therefore when the changes to the upper half were made the same had to be done to the lower half. The decrease in the tube for the liquid was thought to be necessary as to increase the pressure created in the tube for the air in order to increase the airflow through the whistle creating a more pronounced sound.

Remembering the information presented in chapter 1 regarding the economic status of our target group it was concluded that further inquiry in other solutions would not be needed. Since, proof of concept has been established the selected materials for the manufacturing of this product are silicone for the structure and the plastic for the small whistle making this quite inexpensive for mass production, cost of production development aside. When it comes to knowing the quantity of oil dispensed it will depend on the ratio between the two openings.

As seen above, the author was determined to manufacture a functioning prototype. However, using a 3D printer has proven insufficient for such manufacturing given that the author was incapable of producing said prototype after dozens of experimentations. It was concluded that the printer used as well as the filament was insufficient in terms of properties to properly print so many small details and make an airtight solid.

Furthermore, based on the previous experimentation with prototypes it is the authors hypothesis that with proper equipment it is possible to produce a fully functioning prototype. This experimentation would feature heavily in a future product development. Moreover, in the imagined final version, this would be a product which thanks to its simplicity will require no special maintenance thus no additional cost for the final consumer. As for the ease of identification, the bottle on which this product will rest has already a strong identifiable character.

Finally, when it comes to the aesthetic of this dispenser the color selection is two highly contrasted colors for easier distinction. Keeping in mind that this product is targeted at people with various stages of sight loss and as it was discussed in chapter 2.2, bright and contrasting colors can make identification of objects much easier with people with severe sight loss but not completely blind. The visuals for this are shown and discussed at length in 4.2 and 4.3.

4.2. Concept for oil dispenser

As it has been established thus far, the pour spout will visually be quite similar to a standard one and will fit onto the bottle in the same fashion as seen in figure 39.

Figure 39 – Visual representation of the pour spout mounted on a bottle

The oil dispenser is essentially a modified pour spout. The bottom half of it is standard for a pour spout in that the outer part is characterized by three flexible, equidistant disks which serve the two purposes of fitting snugly in the neck of any standard 1L bottle of oil, olive or

another, as well as acting as an isolator so no liquid spills out as represented in figures 39 and 40.

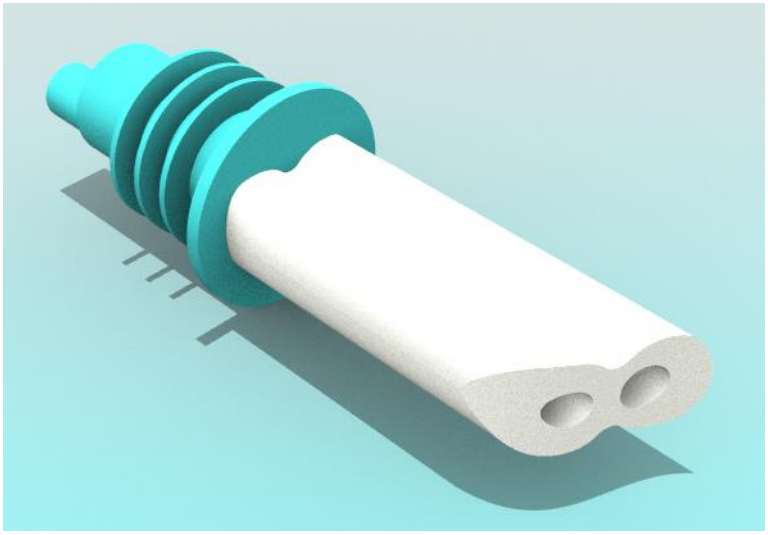

Figure 40 – Isolated rendering of pour spout.

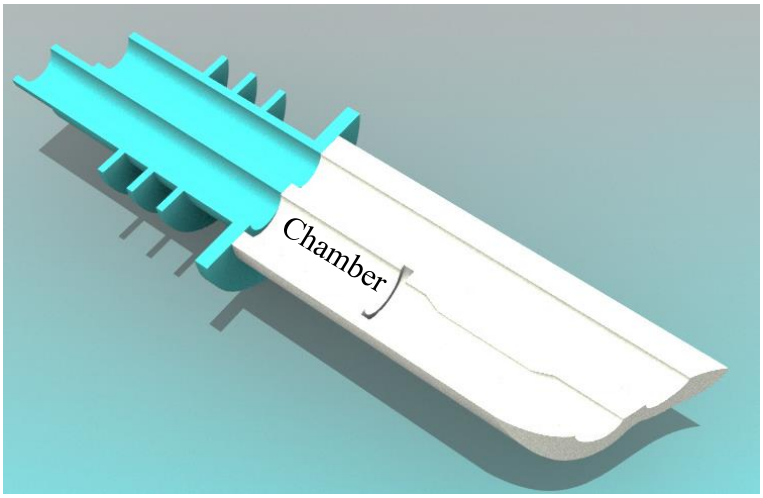

Figure 41 – Section of pour spout showing the chamber for the mechanism.

The top half, which sits above the neck of the bottle, is also quite similar to a common pour spout. The difference between what is readily available on the market and this design is observed in the cross section. The entirety of the pour spout, top and bottom halves, share the two tubes in the vertical cross section, one for air to go in the bottle and one for the liquid to pour out.

It was found in the previous stage that simply adding a chamber for a sound mechanism might not, in fact, be sufficient to produce sound (figure 41). So it was decided to add an extra design

element wherein the air tube will narrow towards the whistle to create a stronger airflow in order to produce a louder sound. The chamber serves the objective of holding the sonar mechanism which will produce sound every time the bottom is inclined and air starts flowing in the bottle.

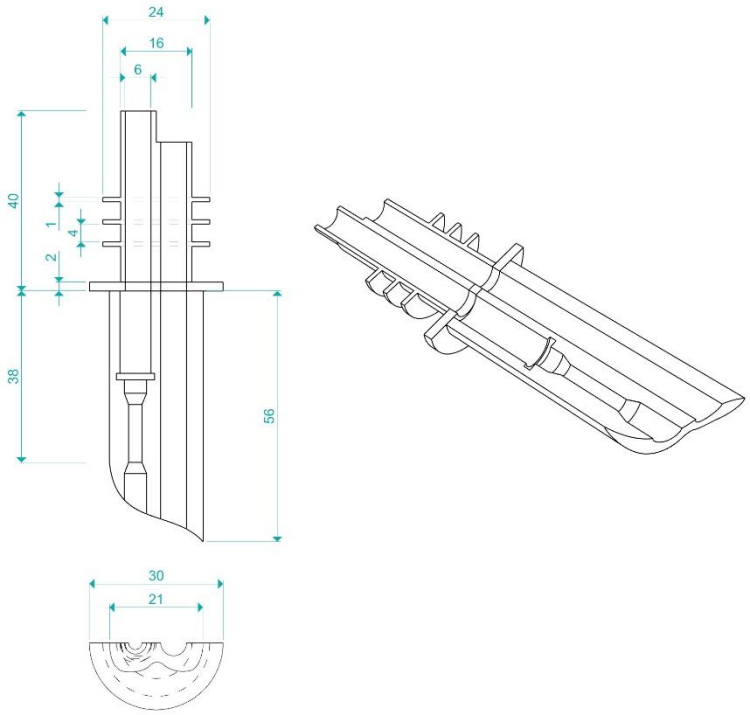

Figure 42 – Technical drawing of section view of oil dispenser.

This whistle-like element is what accounts for the sound produced when using the product. This sound will alert the user to the flow of liquid. The louder the sound the heavier the flow and the contrary will also be true wherein the lower the sound produced indicates the light flow of liquid. This distinction is useful in order to alert the user that the bottle is getting empty and it will soon be time to refill. As seen in figure 42 the oil dispenser is slightly larger than the market standard in terms of length of the top part. This decision was made in order to give enough space for the air to flow with the necessary speed required to produce sound in the prototype version. It is possible that later on in production this measurement could be revised. However, all the measurements related to the proper fitting of the product in the bottle neck are within standards and depenent on the size of the bottle neck.

As for material selection it is decided that the bottom part of the dispenser which is inserted in the bottle will be made of a flexible plastic like silicone while the top part needs to be more

rigid and could be made in either a stiffer type silicone or plastic. This selection is based not solely on functionality and ease of manufacturing but also took into account end of life of the product opening the door to recycling.

The shape of the bottom half is easily produced by creating a mold as its symmetry and cavities are appropriate for injection molding as a process of manufacturing. Similarly, the shape of the top half shares the same characteristics but will need two molds for each longitudinal half and the two pieces can be joined at the end. Drawing the attention to the outer shape, the reason for it not being a simple cylindrical shape is to save material. By choosing to design the outer surface in a "8" shape material can be saved in contrast to a full cylindrical shape.

4.3. Implementation experiments on spice dispenser

A resumé of the identified requirements of the herbs and spice dispenser may be necessary to begin with:

- standardized accessories -fitting for standard jars of common Portuguese brands of herbs and spices
- almost no physical effort required to attach the product onto the jar
- little to no effort in understanding how the product works
- easy to use and reliable dosing
- prevent clumping due to steam

As was stated in chapter 3.1 one of the main issues with the standard store-bought spice and herb jars is that while the openings seem to be designed in relation to the product inside. However, as was illustrated, those openings are far from reliable as they either dispense too much or too little herbs or spices with seemingly no way to control or predict which one it would be. This stage of the process began with idea generating through sketches.

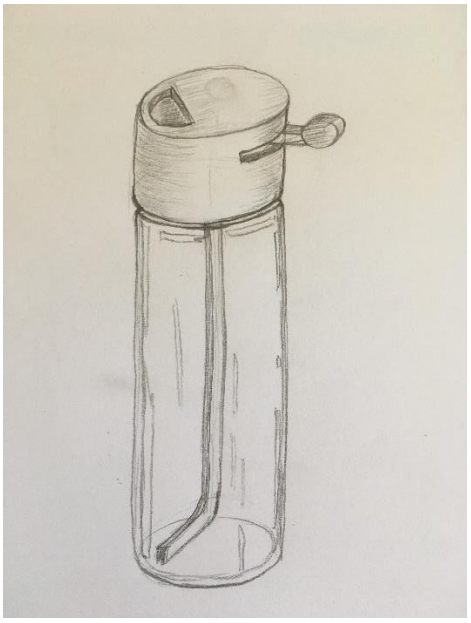

Figure 43 – Initial sketch of what the spice dispenser could look like based on the research done this far.

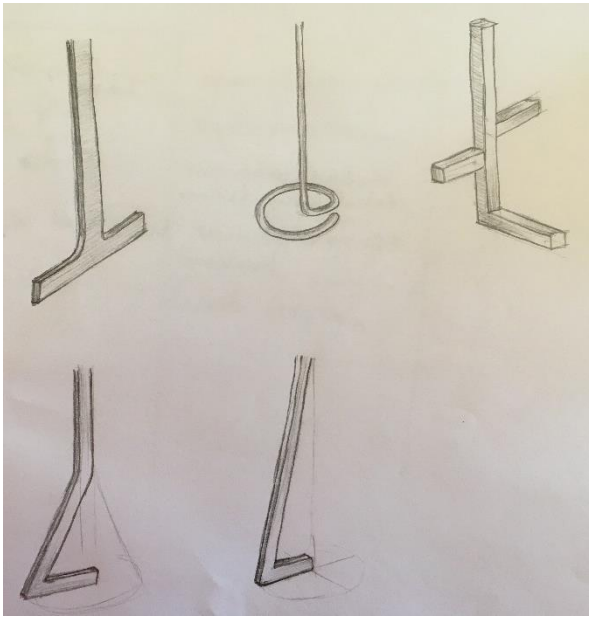

Figure 44 – Brainstorming various shapes for the mixing element of the dispenser.

Based on the analysis done in the previous chapter on customer requirements, it was clear that the starting point is the standard jar size for spices. Evidently the dispenser is expected to fit nicely in the jar, somewhat maintaining the top portion within the size of the standard caps as seen in figure 43. The focus later fell on the mixing fixture and the various geometries that it can have. Shapes were devised (figure 44), at this stage, only considering the primary function

of loosening the clumped products and secondary function going as far around the jar as possible.

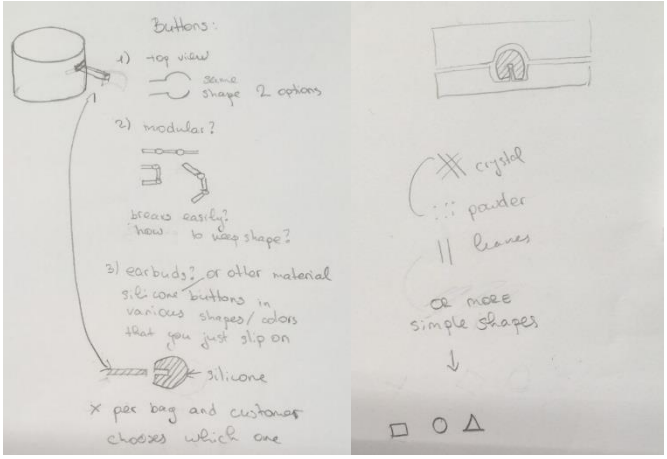

Figure 45 – Idea generation for the button.

Lastly, the focus shifted to the button of the dispenser, which as previously stated will be the second most touched part of the dispenser. Some of the ideas, as shown in figure 45 included mirroring the same shape and using some type of a modular design where the customer can create various shapes. Ultimately, the idea that was kept was the one based on the silicone inserts provided for certain type of earpods, where upon purchase of the earpods the customer receives within the package a set of 3 silicone attachments in different sizes. By implementing the same logic, it was thought that upon purchasing this spice dispenser the customer will receive a number of silicone button attachments in high contrast colors (for partially impaired) as well as a selection of varying patterns. In this manner, the customer can create various combinations between the top of the dispenser and the button so as to easily differentiate between the containers' contents.

Having clarified the focus points, it was decided to begin working in a practical, physical manner, so the process of prototyping was initiated.

The proposal is composed of the following main components, which have been made through additive manufacturing using a desktop 3D printer and a spring extracted from a hair clip. The deconstructed product is made of a mixer with a button extension in the top (figure 46); a cap for the opening in the lid (figure 47), the top part of the lid with the opening (figure 48) and the ring which holds all the above-mentioned components as well as a miniature compression spring (figure 50).

Figure 46 – Spice mixer with button attachment on the upper right.

Figure 47 – Cap for spice release.

The elements in figures 46 and 47 are to be united with the cap in at the top with a screw or a clip insertion. The spice mixer is to be one piece with the cap for spice release so as to be able to mix the spice as the cap opens thus insuring no clumps and an even flow.

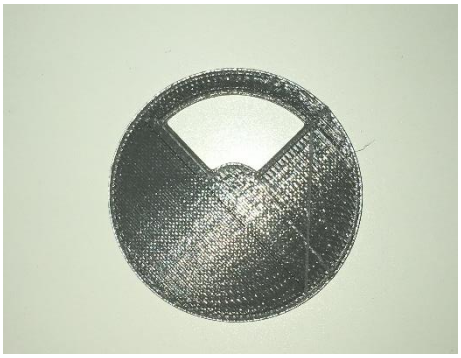

Figure 48 – Top part of the lid with hole for the spices to exit the jar.

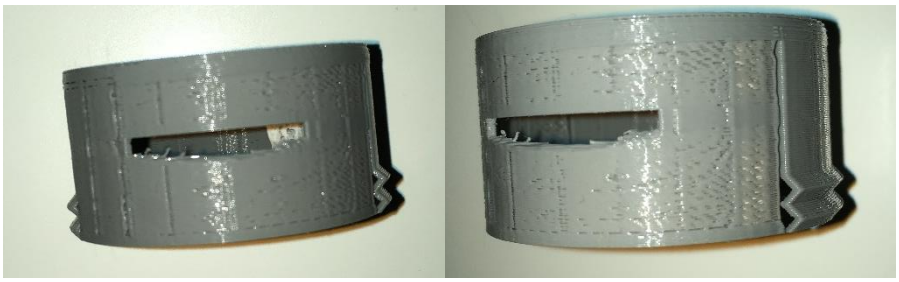

Figure 49 – Lid with opening for the button and easy click sides to fix onto the jar.

Meanwhile the lid is characterized by a slot on the top for the spices to come out (figure 48) while the sides have two slits which are somewhat flexible as to allow for a push/pop mechanism for easier application on the jars (figure 49). Additionally, the side has another opening, this one horizontal, for the button to pass through and allow for the movement that will release the barrier on the top opening when pushed.

Figure 50 – Miniature compression spring.

This will be both aided and controlled by a small spring which will ensure a quick open and close so that the flow of spices can be controlled (figure 50).

As the 3D prints continued to pose some issues in regards to proper execution of details, the decision to work with a larger model was made. Therefore, the larger model was to have all the same elements in a larger scale made to fit a small jam jar (figure 51). This was used as means to be able to work through some of the more demanding design decisions such as small details on the mechanisms and other small elements as stops or jambs (figure 52) as well as to clarify assembly options and proof of function. For example, the elements from figures 51 and 52 assemble in the following way: the screw with the lever is inserted into the hole in the

valve and both are inserted into the mixer. Ideally this would be done either by adding an actual screw element to the lever and the mixer or by using glue so the various parts will move as one. Then the combined lever-valve-mixer is inserted in the slot on the inside of the lid, hence the trapeze shape on top of the screw. What will be left is to fix the small spring with one side on the lever and the other on the jamb on the inside of the lid allowing for the much needed resistance for the spring to function properly.

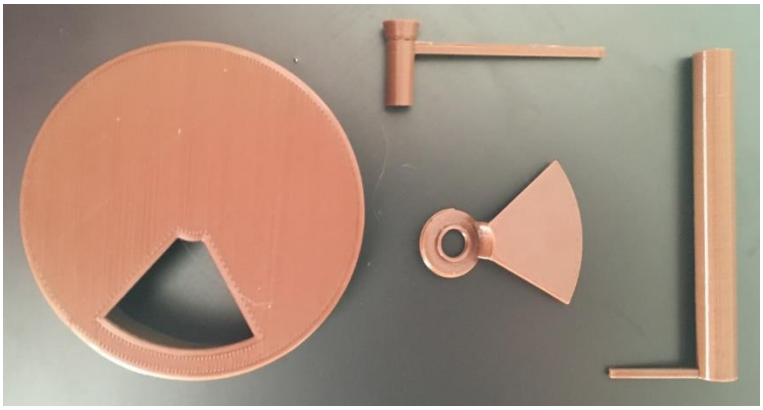

Figure 51 – 3D printed components of the spice dispenser. On the left: lid; upper middle: screw with lever; lower middle: valve; right: mixer.

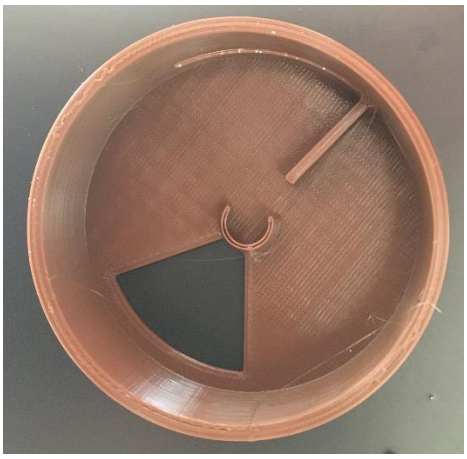

Figure 52 – Bottom view of the lid.

As the spice dispenser was becoming more and more defined from a functional perspective it was determined that the focus must then fall on the aesthetic decisions of the design.

4.4. Concept for spice dispenser

The process of coming to the final decisions for this product was meticulous and exhaustive. Once the mechanism was determined, the emphasis fell on the user experience, in that every option was carefully analyzed through the lens of the user. This included cost, so the material selection had to combine the user requirements for touch differentiation as well as price and even packaging.

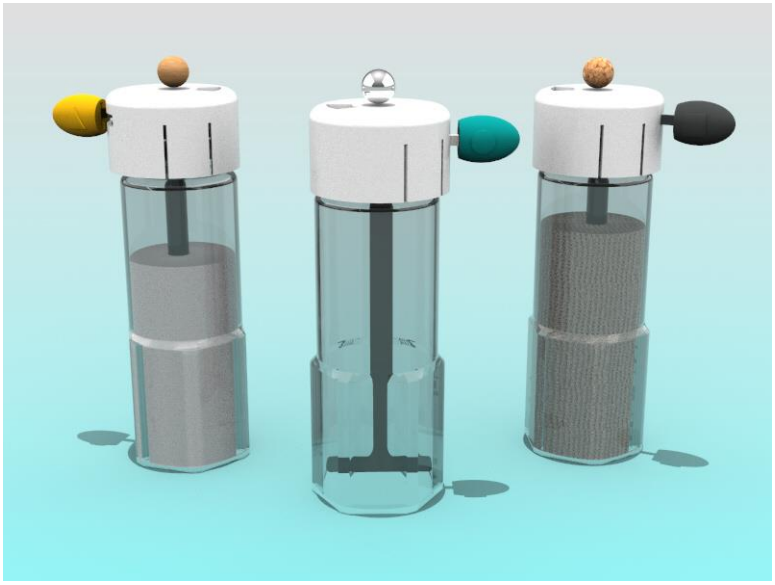

Figure 53 – Final concept proposal for spice dispenser. Overview.

As seen in the renderings figure 53 some elements have been modified and/or changed. Notably, a new element has been added to facilitate manufacturing and functionality, which is the sphere on top of the lid. For manufacturing purposes and maintaining the structural integrity of the product it has been decided to manufacture the lid from a singular, neutral material: plastic. The sphere on top will be made of three materials for the three categories i.e. cork for crystals; wood for dried herbs and brushed aluminium for powders. These spheres have the additional function to cover the screw on top of the lid which will hold together the lid, the button and the mixer, so as to ensure mobility of the elements.

Lid:

The shape of the lid is a simple open cylinder with a rounded top for a clean and soft aesthetic as well as a pleasant to the touch shape. It is equipped with two slits on each side to provide elasticity to the lid when pushed down on the jar in order to fit and to clip to it easily thanks

to the added rim inside (see figure 54). There is also a horizontal slit on the side through which the button can slide and pop out on the other side as well as the hole on the very top of the lid to release the spices as shown on the right of figure 55. The lid is also the "glue" that holds the product together, which translates in a few extra elements on the top inside. One such element is the stopper as seen on the left of figure 54. The stopper is there so the spring can be fixed to it on one side and the other can be fixed to the button thus creating resistance for the spring and therefore the button. There is also a conical insert for the button on the center top so assembly is simplified and functionality maintained without the addition of an actual screw. All of these details make the decision for material selection somewhat limited. Few materials can be easily and reliably molded into a complex shape like this and fulfill the additional requirement of elasticity and strength, so plastic was selected for these reasons.

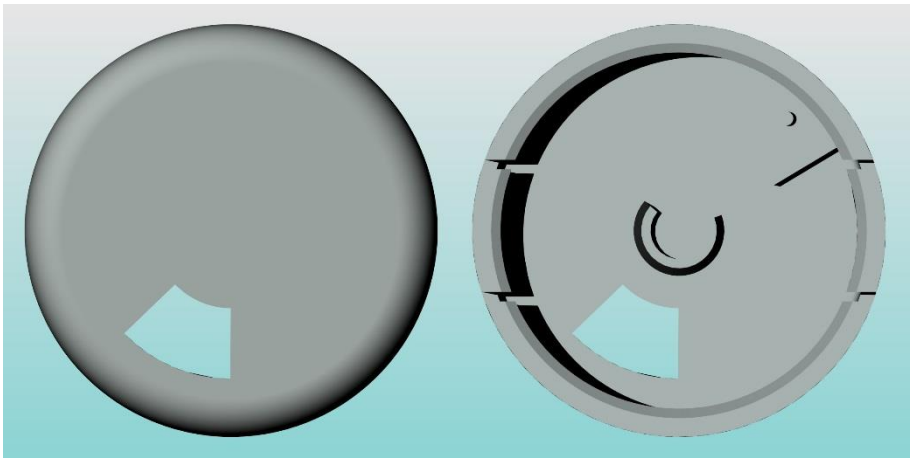

Figure 54 – Left: under view of the lid for the spice dispenser. Right: perspective top view.

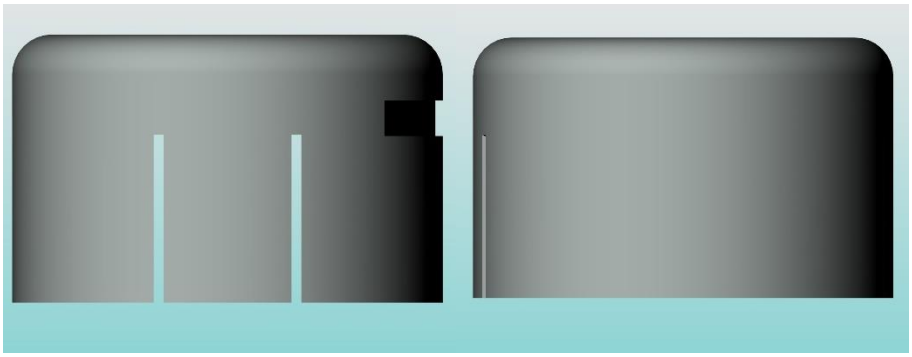

Figure 55 – Side views of the lid for the spice dispenser.

In figure 56 can be found the general measurements for this element. The measurements seen here are not the definitive final ones as changes will certainly be made for production, taking

in consideration the proper material and the proper manufacturing techniques. However, the general measurements like the height, width and anything pertaining to the proper fitting on the jar will remain the same. The ones that will probably undergo modifications are relating to the smaller details and will consider the properties of the final material notably the elasticity.

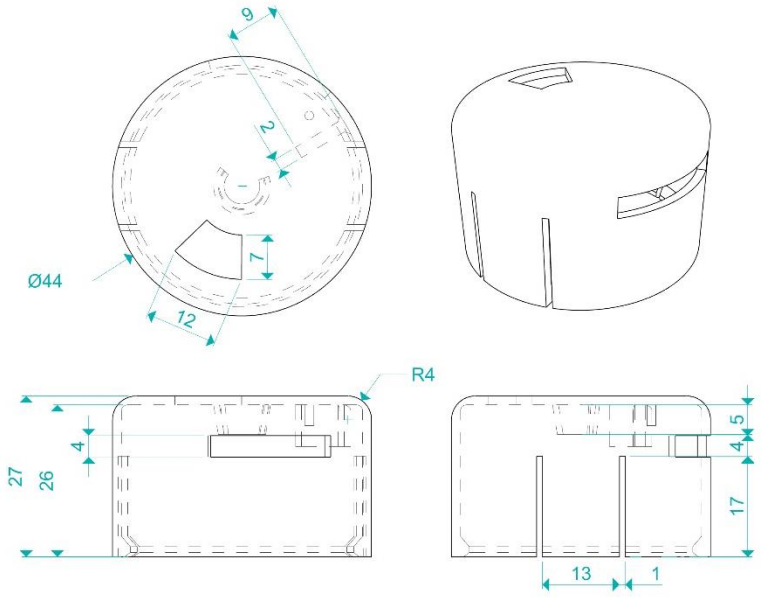

Figure 56 – Third angle projection drawings for the lid.

Screw, valve, mixer:

These three elements move as one, therefore they will be grouped together and analyzed as one. The screw and button lever both make up the first part where the bottom half of it is a square shape to guarantee simultaneous movement of all the three elements and easy assembly. (figure 57). The screw although not really a screw is conically shaped and easily but firmly inserted in the corresponding conical insert on the center top on the inside of the lid as illustrated in figure 58.

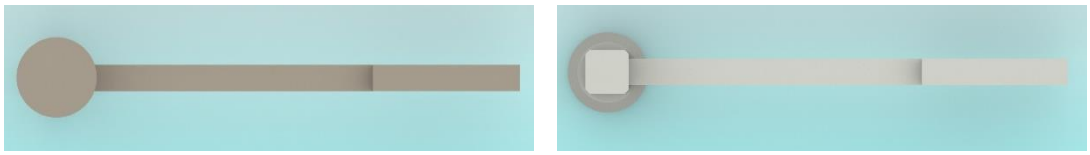

Figure 57 – Left: top view of screw element. Right: bottom view of screw element.

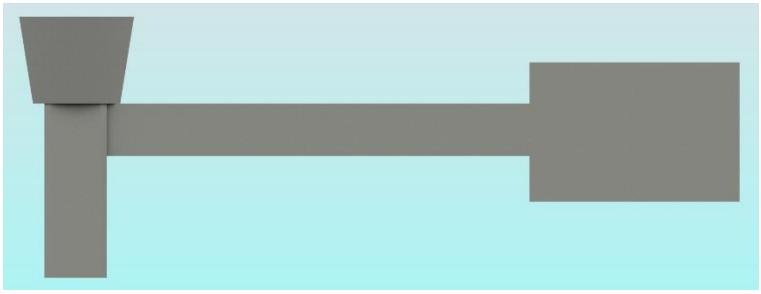

Figure 58 – Side view of screw element.

Following, the valve element. It is attached through a small column to a disc with a square shaped hole in the middle. The valve is inserted onto the screw element in the correct position (angle) which in production can be achieved with an assembly mold. All of this is observed in figure 59.

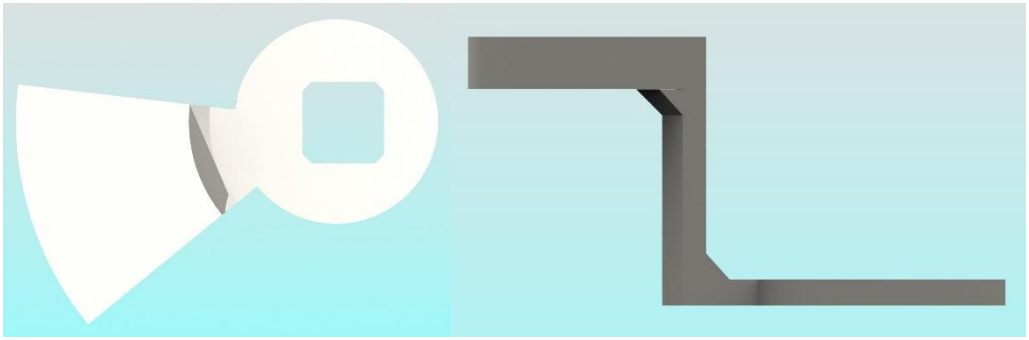

Figure 59 – Top and side view, left and right respectively, of the valve.

The final element is the mixer. This element is quite straight forward and simple. The square shaped hole on top shown in figure 60 is for the screw and valve to go into. The column is approximately the same length of standard spice jars and is in a T shape (figure 61).

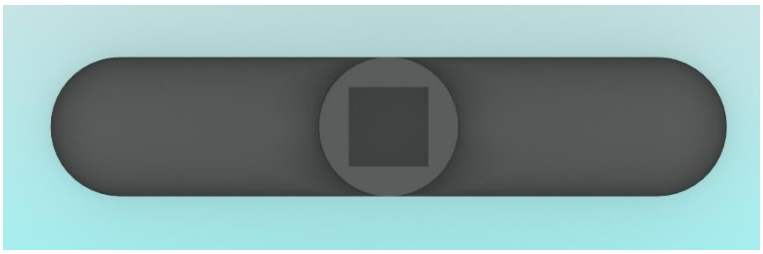

Figure 60 – Top view of the mixing element showing the square shaped hole on top.

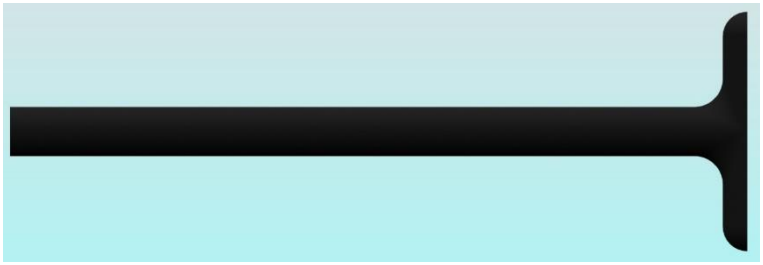

Figure 61 – Side view of mixer.

All three of these parts will also be made of plastic for the same reason the lid is. Given the complexity of the shapes and the necessity to be light, easily cleaned, safe for food contact.

Buttons:

Next, there is the three silicon insert buttons in different high contrast colors for people with limited vision as well as three geometric figures embossed on the side as shown in figure 62 (1 figure per color, example: red button with a circle). These buttons will serve as further distinction, for instance wooden sphere on the lid combined with red button can mean that the container contains a dried herb (sphere), specifically oregano, and so on. On the bottom there is a slot (see figure 63) so the button can easily be inserted on the lever of the screw.

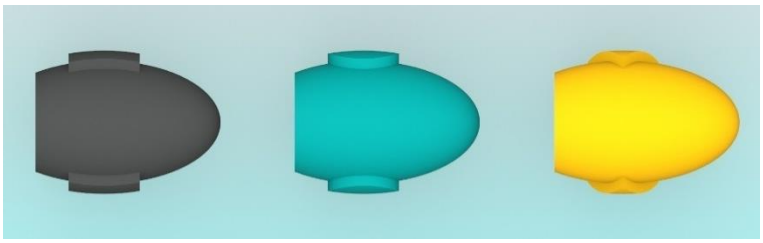

Figure 62 – Front view of silicone buttons with all three patterns.

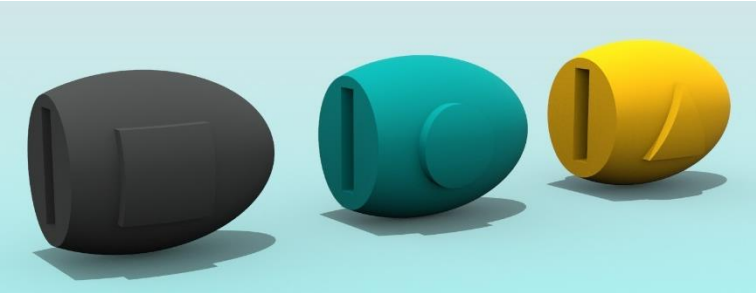

Figure 63 – Perspective view of the silicone buttons.

From a manufacturing perspective this is advantageous as there will be a need for only one mold necessary for the plastic lid, separate molds for the screw, valve and mixer, three molds for the silicone buttons and three beads or spheres from the three materials which are easily mass produced using for example an automated lathe. This way facilitates assembly as well in that all the elements are clearly different enough from one another so there will be no confusion what goes where. In addition, the assembly of the spheres will cause no confusion as it will be just a question of separating the correct quantities. Supposing that the total amount of products to assemble is 3000, simply divide that by 3 and mount the 1000 spheres on the 1000 lids.

There are still a few details that will need to be re-evaluated if and when a product like this will be produced. Often times according to production ability and limitations changes are made to facilitate production and to smooth out function shortcomings, especially in a product comprised of a variety of materials, each one having its own set of quirks and peculiarities. One such aspect, which could become problematic is the spring for the button. It could get stuck with spices and herbs after some use. A solution which was explored but ultimately abandoned was to encase that part of the mechanism in order to protect it, however that would have complicated assembly if not rendered it impossible.

Choice of material for this second product is mirrored in the choice for the previous one. The reason for choosing plastics and silicone here also is not only based on having a continuous design language between the two products but also considering end of life of the product. Apart from the environmental and financial advantages of using recycled materials this will also play a big role in the business plan which will be presented in the next chapter.

4.5. Summary of concept development

After a contextual study of the market beginning with world statistics on the target population explaining the demographic peculiarities such as economic status and ability (or lack thereof) to perform ADLs this work proceeded by presenting existing solutions to some of these limitations. These solutions were built upon by a dive into the neuroscience that allows them to perform their required function. Later on, the solutions used by some of the devices already in circulation along with the ideas gathered by the scientific analysis were implemented in the brainstorming and initial design process. This of course led to the topic of this chapter which focused on the introduction and examination of the final concept designs along with visual representations, problems encountered and solutions proposed and finally the possible limitations. The designs presented previously are not free of critique or reproach. It is evident that like with all product design there will be aspects that would need adjusting. The more important of these aspects will be the proper functioning of a sound mechanism for the oil dispenser and the definition of an exact amount of released seasoning in the spice dispenser. Considering things like proper final materials to be used, specific mechanisms, production etc. changes to the designs presented here will inevitably occur.

5. Business model

Thus far the work has investigated the target demographic i.e. persons with visual impairment focusing on the amount of people affected and the various manifestation of the different types of impairment therefore presenting the motivation and goal of this work

In order to understand how to better cater to the market of persons with visual impairment several topics had to be investigated. One was a dive into the neurological aspects of losing one sense and how the brain compensates for this loss. This combined with following study on various devices and assisted technologies lead to various ideas about how to optimize the

design in order to stimulate the brain so that sight will not be a deterrent to proper execution of ADLs.

Chapter 3 was structured around the implementation of all the previous information and how it led to hypothesis generation around the mechanical and the sensory elements of the design concept. It concluded with a presentation of the two final proposals, one for the oil dispenser and one for the spice dispenser respectively.

This conclusion served as an opening for chapter 4 where the final two concepts were presented along with design and general measurements. It was shown how the work done in previous chapters influenced the decision making when it came to the design of the products. For instance, the choice to have spheres on top of the jars was based on the study of neuroscience and how the brain can use the sense of touch to compensate the lack of sight hence the choice to use different materials. Those different materials were chosen based on associations between the sensation when touched and the contents of the jar, e.g. wood is comparable to dried herbs; brushed metal is reminiscent of powder and the rough surface of cork is similar to salt crystals.

The latest chapter will focus on the model for a potential business created around this work beginning by analyzing manufacturing, then moving onto services and support, and lastly presenting an overview of a complete business model.

5.1. Manufacturing and assembly

With the demonstration of the final concepts in the previous chapter it has been established that the majority of the materials which will be utilized in these products will be plastic and silicon. This is not taking into consideration of course elements such as the spheres on top of the spice dispensers or the whistle mechanism for the pour spout. The manufacturing of these additional elements will be discussed in less details at the end.

Based on the design, the materials for the main elements and the batch size it has been determined that the most appropriate manufacturing process is injection molding. Injection molding is a process which uses molten material which is injected into a mold and solidifies upon cooling. This entails making molds of the various parts and building the machine which is the costliest part of this type of manufacturing. However, the high cost of the machines and tools is acceptable when production is sizeable specifically above 10 000 units, which is less

than the desired production size of this project. The machine is composed of three major parts made from metal which are the injection unit, the mold or tool and the clamp as seen in figure 64.

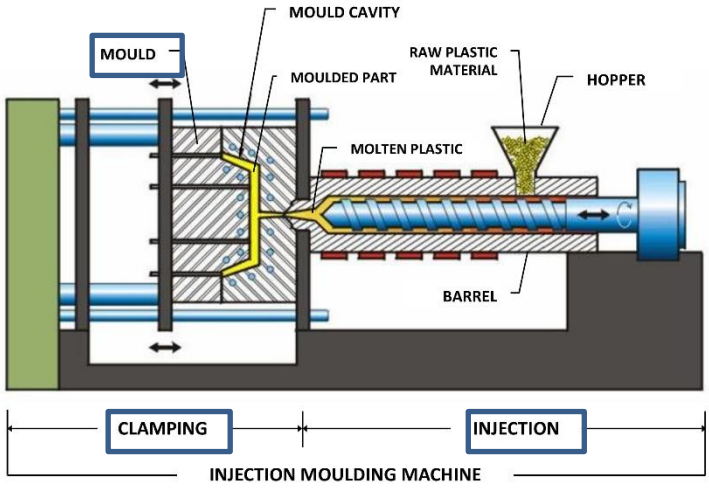

Figure 64 – Schematic of an injection molding machine.

While the machine itself is standard the part that is specific to the product is mold. That is the part that will need to be custom made. The mold is usually a two-part tool with either two negative halves or one negative and positive in order to create the desired shape as illustrated in figure 65.

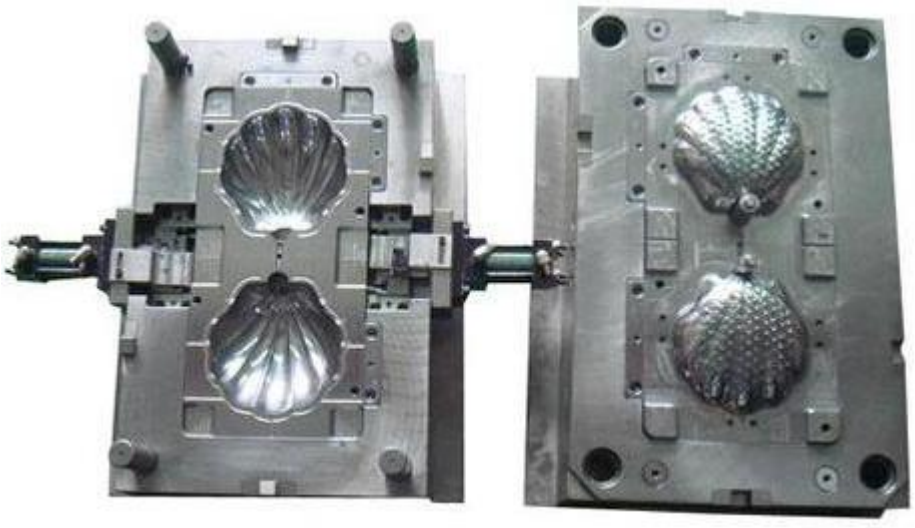

Figure 65 – Injection mold. Negative part on the right and positive on the left.

The reason for the selection of this process is largely based on the design. This process is very well suited for large production of small detailed components made from thermoplastic and thermosetting polymers therefore, perfect for the elements presented in the two products presented in this work.

As mentioned previously there are other components to these two designs that do not fall under the same criteria notably the spheres on top of the lid of the spice dispenser, the spring, and the whistle for the oil dispenser. The last two will be provided by suppliers who already produce these parts for other uses while the spheres will be made using a copying lathe. Since all three materials – wood, cork and metal can be transformed using conventional machining, specifically by use of a lathe. The lathe is a machine which fixes the raw material in a solid shape on a y axis making it spin and the cutting is done by introducing perpendicularly a blade. This process is best suited for round, cylindrical and symmetrical shapes such as spheres.

Finally, it is time to address the question of assembly. Given that all the elements of the products are easily distinguishable from each other by shape, size and/or color assembly will not be a confusing task. However, it will be a timely and precise one thus the proposed assembly can be made adopting a manual assembly chain. The reasoning behind it being manual instead of automated is that while the production batch size may seem large it is not nearly large enough to mandate the designing and building of special assembly robots as those are used for production batches in the hundreds of thousands or for consistent production of large components where manual labor is not physically viable or is too slow. It is possible that in the event of market success of these products the production and specifically the assembly will be revisited to accommodate for a larger scale production.

End of life of these products has also been a point which will be discussed both as part of manufacturing and in the relationship the business will have with its customers. Being conscious of the environment, end of life of these products must be evaluated on a few fronts. After several years of everyday use, the products will be contaminated by grease and spices. While the spices do not pose much of an issue since a simple wash should clean off any residue, the oil could pose a bigger issue. Therefore, recycling processes will have to be researched further in the future.

5.2. Business model

As the questions of manufacturing and assembly have been answered it is now necessary to present a viable plan for the establishment of a business based on the two products presented here and the accompanying ideas. When it comes to the business model it is worth mentioning that in its final version it will be devised with the help of professional business consultants, PR and marketing experts etc. What will be presented shortly is a guideline of what this business would preferably look like without necessarily all the details of how it can be achieved.

It has been established thus far that motivation behind this work is to above all help improve the QoL of persons with varying levels of visual impairment in regards to the eased execution of ADLs and IADLs. It has also been explained in detail in chapter 1 that persons with a higher level of impairment often are part of the low-income demographic largely due to the lack of employment as a result of their impairments. Therefore, this business model will be similar to that of a not-for-profit organization with slight modifications in certain areas. For example, it is a business that will largely depend on sponsorships and could generate small profits necessary to remain operational. Following is an explanation on how it will achieve both.

First and foremost, it is important to argue who and why would sponsor a business such as this one. Partners will include national associations for the blind such as ACAPO (Associação dos Cegos e Amblíopes de Portugal) and equivilent associations in other countries that will provide awareness for the product and can act as a direct to consumer distributors. When it comes to the revenue streams (see far left and bottom right of figure 66) there are a couple of possibilities – large companies that are already partial to the cause of helping people with disabilities and celebrity chefs with similar interests.

One such company is OXO. OXO has already been mentioned in chapter 2 and is a company which designs and produces accessories for the home with a focus on kitchen accessories. This company is already producing products which fall in the same category as the ones presented in this work and is invested in the concept of Universal Design or Design for All as they themselves explain on their website [60]. As a large successful company with an established name in the industry it is the perfect example of a company that could be interested in a partnership or a sponsorship.

Additional partners may include celebrity chefs and one example has already been mentioned in chapter 2.2.3. Her name is Christine Ha and was the first blind contestant on MasterChef USA and subsequently won its third season in 2012. She was already contacted in regards to this work and her quick response and helpful insights are proof that a partnership is possible. Given her personal experience and professional success Ha has presented herself as a potential ally and partner in an endeavor as this one.

When it comes to generating revenue based on sales the proposition centers around the customer segments (see right-hand side of figure 66; Customer relationships, Customer segments and Channels). As previously stated, the customers of these products include many low-income individuals. As such, there are three segments – medium income, low-income, and very low-income customers. Therefore, customers who can pay full price will have access to the product via online shops and will accumulate points which can be then donated to low income customers by being converted into discounts by use of promo codes, for example. Thus, persons who are unable to pay full price will still have access to the product but a more convenient price. Another proposed way to reach the last two segments is by employing a recycle policy. This will allow persons to send back already used or broken products back to the company and will be rewarded a discount for the next purchase which can again be donated to less financially capable customers. Finally, the business will also be crowdfunded through platforms such as Kickstarter and GoFundMe where they can also donate their accumulated points and discounts to be used for supplying the aforementioned associations with products to be given away free of charge the customers who are unable to pay.

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="2">Partners:
Sponsors:
celebrity chefs with foundations
Distributors
Suppliers:
Factories:
manufacturing
packaging
Agencies:
marketing</td><td>Design -R&D
Tech support for websites</td><td rowspan="2">Problems solved:
less dependency for ADLs
Needs satisfied:
independent food preparation
Values delivered:
good design,
customization,
newness,
accessability,
usability,
does the job</td><td>Customer Assistance
Membership personal codes</td><td rowspan="2">Segmented niche market:
Financial:
full price
assisted price through membership
free through associations
Target:
Visually impaired
Novice cooks
Children 10+</td></tr>
<tr><td>Key Resouces
Investments
Raw material
Designers</td><td>Channels
Awareness through associations, sponsorships, social media
Online shops</td></tr>
<tr><td colspan="3">Cost Structure
Biggest cost: manufacturing and distribution</td><td colspan="2">Revenue Streams
Revenue Streams through sponsorships, full price sales and crowd funding to sustain business so customers who cannot pay full price can still have access to the product</td></tr>
</table>

Figure 66 – Business model.

The send back possibility comes from the idea of using as much as possible recycled raw material. This is important as a side mission of this endeavor is to be environmentally conscience. This desire coincides with the business model as it can alleviate costs and gain support from environmental allies from other industries as possible partners or sponsors. By sending back broken or worn-out products not only do customers get reimbursed in a way but they also help the continued production of the products. As the main aspects have been attributed to partners and suppliers it is important to discuss the role of the business once financing, manufacturing and distribution are accounted for.

The key activities of this business will undoubtedly be design, research and development, and technical support for the online shop, crowdfunding profiles and marketing, as shown in the second to the far-left column of figure 66. Once the business has been established with steady financing and manufacturing, what will be left is managing distribution to associations, creating and maintaining an online presence and the development of new similar products.

5.3. Summary

While the model described in the previous sub-chapter is not fully developed and complete it does illustrate the main points of the proposed business. The most important aspect is that this will not be an only for-profit business, since if it was it will defy the basic motivation behind this work which is to help improve the QoL of persons with visual impairments, in that most of the target group will not be financially capable of purchasing this product designed for them. Consequently, a model was devised where the main revenue streams will come from sponsorships and crowdfunding and a small portion will be provided by paying customers. This will ensure that the business will have enough capital to stay operational and cover costs. Since the main objective is to improve people's lives it was established that this help will come from others as well, in the form of donations and discounts offered from paying customers to those who can afford to pay only partially. Finally, the business aims to be environmentally conscience which it will achieve by using recycled materials and offering a send-back policy to reuse or recycle old or broken products in exchange for "store credit", membership points or discounts.

With the formulation of this business model all the stages of this work have been completed in logical order. Starting from the introduction into this market from a social and economic perspective and explaining how being limited in ADLs affects QoL it transitioned into the

study of the causes and manifestations of visual impairments. The latter was expanded on by presenting current solutions to some of the limitations that life as a visually impaired person can have focusing on solutions while cooking. Having understood those limitations and having studied some of the solutions, it was time to begin conceptualizing the two products. Those initial concepts were then developed into final proposals which in turn were examined from a manufacturing stand point and translated into a business model.

6. Conclusion and future work

The inspiration behind this work was to attempt to argue and then demonstrate the need for and the lateral thinking behind what is commonly referred to as Universal Design. This term is not new nor is the concept, however, the author believes that it is a niche worth investigating and expanding upon further. Where universal design is part of everyday life in most public spaces in the developed world and on the internet it is still hard to find in home supplies and everyday tools. This is the reason behind the idea of working on tools for everyday use by persons with disabilities and more specifically persons with visual impairments. It has been explained in the beginning of this work why developing products such as the ones presented here is not a niche market and that if done right, they do not have to be targeted exclusively at

persons with disabilities but simply could be used by all. As this work is at its end this chapter will first concisely retell all the major elements that made up this work. The focus will then shift onto the analysis of the results and limitations encountered during this work and will conclude with a reflection on the possibility of future work and developments.

6.1. Analysis and conclusions

In the beginning of this work statistics were presented on disability worldwide with an isolation of the numbers relevant to visual impairment. The amount of people for whom life with limited and severely limited sight is often unnecessarily difficult in this day and age is disturbing which is why it was determined that this would be the motivation behind this work. The decision to focus on facilitating the visually impaired in cooking independently was made as a result of the examination of the factors that contribute to the low QoL they generally have in the basic ADL.

This was proceeded by an investigation into the truthfulness of popular myth that when a person loses one sense, the others get heightened in the beginning of chapter 2. It transpired that this is fact, that has been scientifically studied and proven to be true, though the mechanics of the processes involved are still not fully understood. Thus, the exploration of MP, special cognitive mapping and SSD guided the work into the world of assistive technology where a view of the evolution of it throughout the centuries concluded with an overview of the market today. An examination of several first-person accounts of what it means to cook blind and what tricks are used to overcome this limitation was offered. These accounts were used as the base for the development process started in the chapter 3.

All the information gathered up until then was applied in some manner in the hypothesized solutions, including things such as useability and proper function in the dispensing of desired quantities. These solutions were built upon aspects of mechanics and multisensory processing, as well as testimonials of potential customers. This led to the presentation of the final two products this work focused on – an oil dispenser that alerts the user of how much flow is occurring via sound and a spice dispenser with a built-in mechanism which prevents over or under releasing of spices or herbs.

The following chapter 4 focused on the implementations of these hypotheses in a presentation of the prototypes for proof of concept. It was determined that while proof of concept was established a further exploration of product development was still necessary in order to make

a fully functioning product which is ready for market. Nevertheless, a comprehensive analysis of what was learned in chapter 2.1 was used as a guideline to determining material selection and aesthetics. Both of these aspects were implemented by completely ignoring current design trends unless they directly impacted the functionality of the products.

Finally, a business plan was presented where topics such as manufacturing, services rendered and client support as well as a business model were discussed. Given the results of the material selection process i.e. plastic and silicon, the manufacturing of these products will be via injection molding. Next it was advantageous to discuss customer relationships. It was proposed that a membership system be implemented wherein customers can help each other through a customer community and crowdfunding. All this was expanded and incorporated into the final business model. It was made clear that in the event of this project continuing forward onto the market it will be user focused instead of profit oriented. The business will rely heavily on sponsorships, partners and crowdfunding and less on paying customers. Since in its essence the objective of this work is to help people live a better life it was proposed to attempt entering a partnership with celebrity chefs already socially involved with endeavors such as foundations or charities.

6.2. Future work

It should be noted that even with the amount of work that has gone into this project there is still much left to do in order to see it on the market. The research done here is not sufficient as the results have proven the presence of certain limitation which will have to be addressed further. One such example is full proof prototype. What transpired in the course of this work is that designing a well-functioning low technology product using mechanisms is a process that is lengthy and not well suited for 3D desktop printing. The reason why is that this process is unable to produce air-tight leak-free components. The standard filament does not have the correct properties especially elasticity and strength. The tolerance of the printer, even when using a smaller nozzel is not optimal which means that whenever pieces must have a tight fit it is often difficult to achieve. Furthermore, the lack of custom-made components such as springs or whistles added to the difficulty of producing well-functioning prototypes. For these reasons it has been concluded that for proper prototyping and product development other methods with more precision and correct materials must be used in addition to appropriate custom-made components. A possible solution for the manufacturing of better prototypes

which will not leak the same way as the 3D printed ones can be the use of plaster or silicon molds and resin.

Moreover, the products must be tested by a focus group and the resulting evaluations must be implemented in the final design. Additionally, another aspect that can benefit improvement is that, even with the research done for people with mild visual impairment, color selection must be studied and modified if need be. It is expected that by analyzing the results gathered from the product testing in the focus groups ideas about other products may emerge.

The work hereby presented is just one example of everyday obstacles that persons with disabilities (not only visually impaired) experience. It is the hope of the author that other designers in all disciplines will be moved to address such problems with creative and challenging solutions. Designing solutions using the principles of Universal Design is a small but impactful way to improve QoL not only for persons with disability but for everyone as those principles are based on the belief that if a product is designed considering persons with disability that product can be used by abled and disabled persons alike. Also, it is worth noting that from a profession perspective the process of designing such products proves a welcome and stimulating challenge. The fact that there are still not nearly enough everyday objects designed with these principles in mind has left a big space in the market waiting to be filled. This is yet another reason for professionals to take this opportunity and work on using their skills to help people. Therefore, in the event of implementing the ideas and the business model presented in chapter 5, it will be a focus of the business to continue developing such products for other everyday difficulties. It is worth noting that regardless of the possible persuit of developing and growing a business focused on everyday objects designed for all, it is hoped that other professionals will pursue this direction and provide more and more innovative solutions.

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