ArmWear
by Marijn Geurts

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DFI Medisign, Sept.2010

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ARMWEAR: COOL PROSTHETICS

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Orthopaedic instrument maker: "I see it often, when children reach puberty they consider wearing a prosthesis to be worse than just missing an arm"

PREFACE

This great learning opportunity would not have been possible without the help, skills and knowledge of many others, and therefore I would like to start with thanking all of you for your interest and confidence in my project!

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Dr. Ir. Johan Molenbroek, chair of supervisory team,

Dr. Ir. Pieter Desmet, mentor of supervisory team,

Dr. Ir. Dick Plettenburg, DIPO company mentor.

Thank you all!

NOTE BEFORE READING

DIPO

This is a TU Delft graduation project in cooperation with the Delft Institute of Prosthetics and Orthotics (DIPO).

Digital Report

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Figure 105: Easy adjust the appearance of the ArmWear by designing andchanging your DYO-Patches.

ABSTRACT

In The Netherlands, about 3750 people have an arm prosthesis, and the rejection rate is astonishing. Especially in puberty, appearance and fashion become more important. Teenagers can be very honest, direct and even cruel in their opinion, and when you wear 'an ugly prosthesis' the criticism seems credible.

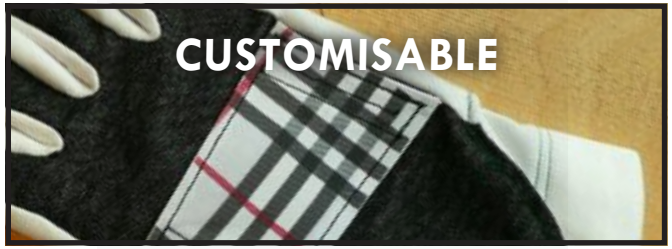
Several studies were conducted with prosthesis wearers, their teenage peers and their prosthetics professionals, to measure the emotions and concerns regarding existing and futuristic prosthesis designs, as well as to evaluate the created concept designs.

Natural appearance is an important issue, and therefore hook prosthetics are unsuitable with strong associations with pirates and robots. The cosmetic glove gets the most positive emotional responses of all existing prostheses. However, it is vulnerable, maintenance sensitive, expensive and unsuitable for physical activities teenagers perform during their active daily lives.

A natural appearance is also achieved when a prosthesis looks like 'it is covering a healthy limb'. This corresponds with prosthesis wearers who see their prosthesis not merely as a replacement of their arm, but as an accessory to their body.

The ArmWear products elaborate on this idea, with a glove and elbowcover that can be worn over any existing hand-shaped prosthesis. ArmWear is a tailor made product, feasible to produce by the piece.

Next to the natural appearance, the functions of the ArmWear allow the teenage prosthesis wearer to quickly add **protection** and grip to their cosmetic glove, and easily **customise** the appearance to match their personal style and clothing. DYO-Patches can be custom designed, in order to create a prosthesis they feel confident with and proud to wear.



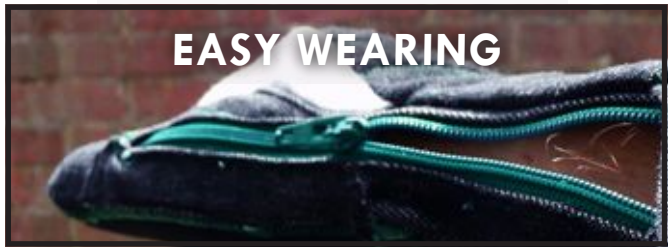


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Figure 1: Australian athlete Heath Francis in his 200m world record race (cat. T46) during the Paralympic Games 2008 in Beijing. Partly due to his specialised prosthetic arm, he won 3 golden and a bronze medal.

CHAPTER 1: AN INTRODUCTION TO PROSTHETICS

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THIS CHAPTER

This first chapter will be an introduction to the world of arm prosthetics.

In the first chapter of this graduation report, the current state of the art in the field of prosthetics will be analyses and determined. A disquisition about the history and current industry will put everything in perspective. And rates about prosthesis rejection amongst children will furthermore determine the scope of this project.

Current trends and technology will also be discussed, and several experts in the field of prosthetics will be contacted for their insights to complete this introduction into the world of arm prosthetics.

The concluding subchapter will unveil the design theme, which contains a short description of the product functionality, target group and situation. And eventually leads to a design assignment as the starting point for this graduation project.

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Figure 2: Arm and hand prosthetics are amongst the most conspicuous prosthetics, even an aesthetic prosthesis like this.

INTRODUCTION

According to the free encyclopaedia of Wikipedia, “a prosthesis is an artificial extension that replaces a missing body part. It is part of the field of biomechatronics; the science of fusing mechanical devices with human muscle, skeleton, and nervous systems to assist or enhance motor control lost by trauma, disease or defect. Prostheses are typically used to replace parts lost by injury (traumatic) or missing from birth (congenital). Products to supplement defective body parts are called orthotics.”

Prosthetics can roughly be divided in two large groups; passive and powered. Passive prostheses can not actively move, and their function is therefore mostly limited to aesthetic properties; looking as natural as possible.

Powered prostheses can be further divided according to their power source. Body powered prostheses are mechanically driven through the remaining body and arm movements, while electrical prosthesis possess motors and electronics to allow movement.

Through all groups, the aesthetics generally follow one of two principles: cosmetic prostheses are visually mimicking normal human morphology, whereas functional prostheses derive their appearance directly from their mechanical components [41].

The most conspicuous prostheses are those that replace lost arms and legs (figure 2), but artificial eyes and teeth are also correctly termed prosthetics. Even frequent surgeries involve prosthetics, in the form of bone, artery and heart valve replacements [36].

Different sources indicate that the number of hand and finger amputations is most frequent, up to 90% of all upper extremity amputations [15, 51]. The frequency of amputation decreases with each bone closer to the body (figure 3), which makes transradial amputations the most frequent *arm* amputation [40, 51].

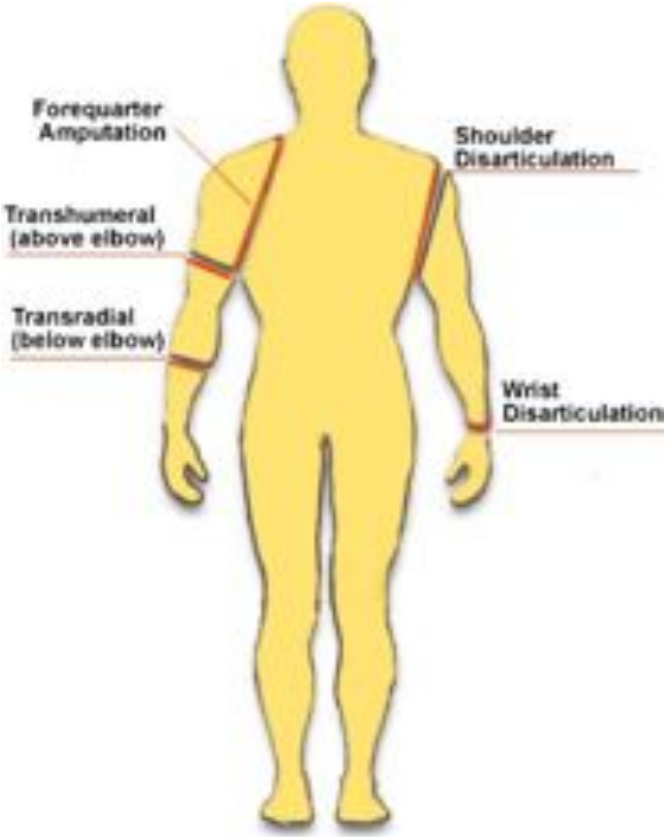

Figure 3: A schematic view on the different levels of upper extremity amputations. The number of for each amputation increases towards the body.

Figure 4: The very early days of the institute that is now known as the DIPO. In the background the Dutch words for some of the requirements for prosthesis are visible: beauty, silence, quick, handy, good, small and economical. Later on these features evolved into cosmesis, comfort and control.

Delft Institute of Prosthetics and Orthotics (DIPO)

Since 1967, the DIPO is one of the leading research institutes for arm prosthetics in the Netherlands (figure 4). The institute consists of about 6 employees, also affiliated with the Mechanical Engineering department of the Delft University of Technology, and continuously complemented with about a dozen PhD, MSc and BSc students [37].

Their products are developed in close cooperation with rehabilitation centres in Utrecht and Nijmegen, and are commercially available under the brand name WILMER [38].

Mission: The Delft Institute of Prosthetics and Orthotics is dedicated to advance prosthetic and orthotic systems, and to increase basic knowledge of human interactions with these systems. The research is conducted in close collaboration with rehabilitation centres to ensure clinical interactions and applications [37].

The DIPO states that the available arm prosthetics are either too ugly, too heavy, too clumsy or a combination of those blunt descriptors [38]. Instead, future research should focus on improving the three main requirements of cosmesis, comfort and control [36, 38].

- Cosmesis is about the looks, dealing with issues like being aesthetically pleasing, soundless and clean.
- Comfort of wearing is about weight, dealing with issues like being lightweight, well functioning, small and clean.
- Control or ease of operation is about feedback, dealing with issues like being lightweight, being useful, functioning fast and efficiency.

Nevertheless, one of the most important issues to get a well functioning prosthesis is feedback to the user [25, 36, 38]. The feedback from the cutaneous and proprioceptive senses from nerves, muscles and skin in a healthy arm are absent in a prosthetic arm. This feedback can be divided into four main categories.

- Tactile feedback to know when the body is touching or being touched. This sense is mainly caused by pressure on the skin. The fingers are well known for their tactile abilities, and are capable of sensing even the most subtle surface finishes.
- Proprioceptive feedback about forces on the body and the relative position and movement thereof. This allows for unconscious movement and balancing without having to visually check where your body exactly is. This feedback is mainly generated by Golgi organs in the tendons, and plays an important role in determining pinch force.
- Pain feedback is a warning signal for the body for possible damage.
- Temperature feedback is the sense and absence of heat, similar to pain stimuli preventing damage from heat or cold.

Lack of feedback in a prosthesis can lead to difficult and even dangerous situations, especially when the prosthesis is electrical powered. Actively involving feedback in a prosthesis remains difficult, and it is an ongoing research topic [36].

Body powered prosthesis are better in giving pinch force feedback than their electrical counterparts, since the wearer can actively control the closing force of the prosthesis.

In general, rough tactile feedback can be obtained with any prosthesis, and balance feedback can be acquired from the stump, but this information becomes less accurate with a smaller remaining limb.

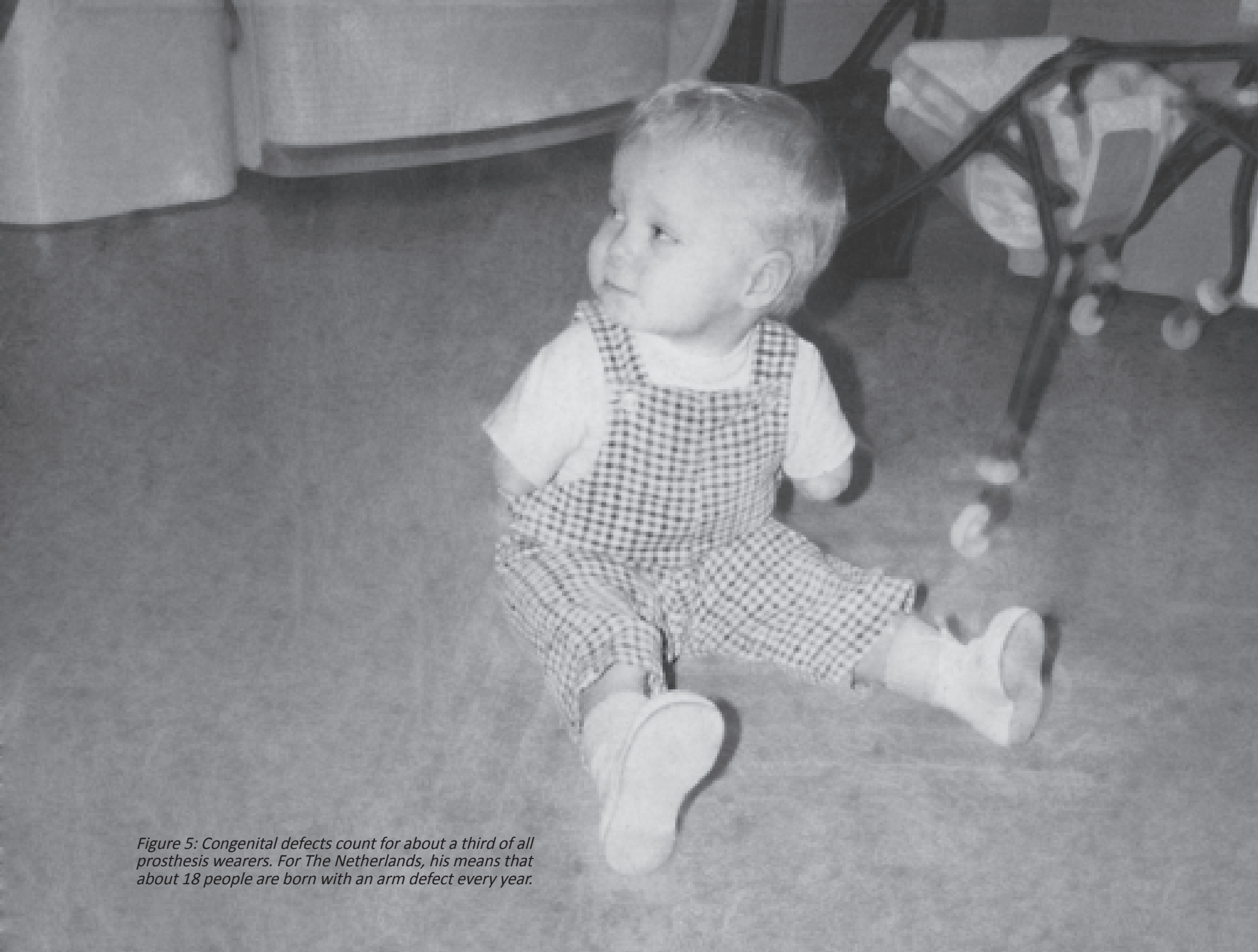

Figure 5: Congenital defects count for about a third of all prosthesis wearers. For The Netherlands, his means that about 18 people are born with an arm defect every year.

INTRODUCTION
INDUSTRY

Research by rehabilitation specialist Van Dijk gives an estimation of the number of people who are considered for a prosthetic arm in The Netherlands. Congenital defects count for about 1350 people (figure 5), and traumatic defects count for another 2400 people. These figures are based on a yearly average of 18 congenital and 40 traumatic amputations, with a respective average life expectation of 75 and 40 years. Since there is no good administration and registration available for arm defects and different sources vary slightly, these figures remain just an estimation. What these figures do show is an arm prosthetic rate of 0,023% of the Dutch population [51].

In comparison, the United States have about 18500 individuals with an arm defect with a population of about 300 million people, thus a prosthetic rate of 0,007% [15]. Globally, an estimated prosthetic rate of 0,01% would mean a possible target group of over half a million people.

The number of people considered for lower extremity prosthetics (legs) is significantly higher than those for upper extremity prosthetics (arms). The number of leg prosthetic users is equally inadequately registered, suggesting a rate up to 0,27% in the US [16], which is about 40 times higher than those for upper extremity prosthetics. This is one of the main reasons that the field of leg prosthetics generally receives more research and development attention; it is economically more attractive.

Another reason is the fact that arms and hands are just much more intimate body parts with a much more complex functionality than legs and feet [41].

Arm prosthetics is a field of industry where the developments have stayed far behind the general technological developments in the last century. Existing companies are working very locally on a small scale with their own specialisations and techniques, resulting in a wide variety of different prostheses and prosthetic components. This makes it difficult to get a good overview of what is already available, both for consumers as other companies. Companies are generally mechanically and technically focussed, leaving the 'design' and aesthetic values unattended [41].

The two globally leading prosthetics producing companies are Otto Bock in Germany with about 4000 employees in 40 offices worldwide, and Össur in Iceland with about 1600 employees in 14 offices worldwide. Otto Bock has several arm prosthetics in their assortment, with a focus on Myo-electric prosthetics. Össur does not sell any arm prosthetics, only supportive orthotics.

Figure 6: This toe prosthesis found on an ancient Egyptian mummy is believed to be the worlds very first prosthesis, it is dated on 1000 to 600 BC.

INTRODUCTION

HISTORICAL PERSPECTIVE

Since the beginning of time, prostheses are made to resemble the body parts that they are replacing (figure 6). The first examples of arm prostheses origin from over 2000 years ago, from ancient Egypt and the Roman Empire. These occasional first prostheses were purely focussed on cosmetics; to make the patients appear healthy and complete again.

In the Middle Ages, more functionality was added to the arm prostheses, to not only resemble the looks but also the functions of the missing limbs. These 'functional' prostheses were very expensive, very exclusive and very awkward [36].

The Industrial Revolution gave way to further developments on arm prosthetics, also boosted by the developments in warfare and the connected increasing number of limb amputees. In 1912 the split-hook prosthesis was designed, just in time to find great application in World War I. Now, almost a century later, this prosthesis is still proven to be one of the most functional prostheses on the market (figure 7) [36].

Developments in the last century have been characterized by attempts to improve the existing prosthetics by automation and use of electronics. Prosthetics have been made electrically powered and actuated by the electric impulses from muscle contractions, the so called Myo-electric prostheses. However, this type of prosthesis is absolutely unsuitable for sub-conscious control of prostheses, and therefore a waste of all research and development efforts [36].

In technological prospect, the future seems to be with a neurological actuation and feedback system; a system where the neurological infrastructure of the body itself can be used to communicate the feedback information in a 'natural' way. However, this very technical type of research is promising for several decades already, while the actual progress is very slow [20] (figure 8). The far future might therefore be characterised by this 'cyborg-like' technology, but in the meantime 'stump-enhancing' body powered prosthetics are most functional and interesting [36].

Figure 7: The split-hook has two fingers, one stationary and one moveable, and is operated by a control cable attached to a thumb-like extension of this finger. The moveable finger is actively opened, and closes passively with a spring or rubber band, also providing the pinching force.

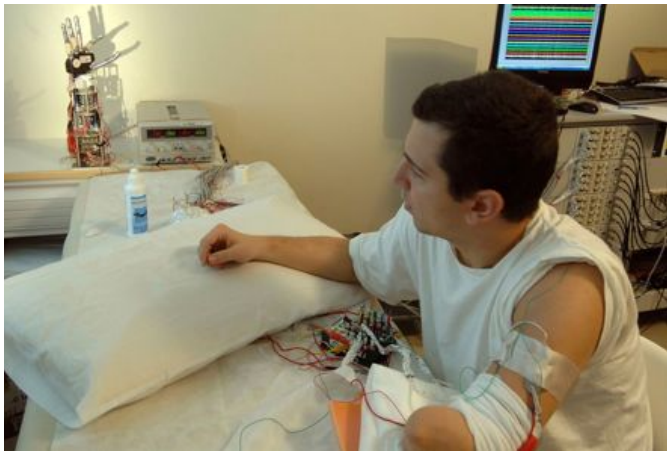

Figure 8: Researchers are trying to create 'mind-controlled' prosthesis for several decades, but this has not led to a commercial application yet.

Figure 10: The WILMER Appealing Prehensor was a redesign of the split-hook prosthesis to improve the appearance and appeal for children between 4 and 9 years old. Due to the success, a larger version was constructed for children till the age of 14 years.

WILMER Open Fitting

Since the 1990s, several promising new designs and principles have been developed at the DIPO.

A new type of socket was developed in the form of the WILMER Open Socket. This innovative design aims on offering the wearer more comfort by leaving much more skin uncovered (figure 9) [34].

Figure 9: The WILMER Open Fitting improves several problems from existing sockets. The new construction is easily adjustable by the patient, and leaves 75% of the skin uncovered to solve perspiration and irritation issues of the skin.

WILMER Appealing Prehensor

The first promising steps have already been made towards a more child friendly split-hook prostheses; the WILMER Appealing Prehensor (figure 10). The prosthesis preserves the functionality of the standard split-hook prosthesis, while improving the outward appearance towards the child and his parents. This resulted in a robust prosthesis that can be personalised with several bright colours [34, 35].

WILMER Ultra Light Hand Prosthesis

Weight is a critical issue for a successful and comfortable hand prosthesis, whilst there were many complaints about this factor in existing prostheses. A redesign focussed on reducing the weight resulted in a carbon fibre prosthetic hand of only 95 grams, this is a weight reduction of 74% compared to existing prosthetic hands (figure 11) [34].

Figure 11: The WILMER Ultra Light Hand Prosthesis has a reinforced carbon fibre shell to provide enough stiffness with a weight of only 95 grams.

Figure 12: The famous confrontation in Star Wars where Luke Skywalker's hand is cut off by Darth Vader, who already has a body of which the majority is cyborg enhanced.

INTRODUCTION

CHILDREN AND REJECTION

It is common knowledge that children have a very high capacity to learn. Their brains are still in development and capable of absorbing everything, from education to locomotion skills. Several researches are conducted in this area, suggesting that it is important that specific motion skills like living with a prosthesis, are acquired as early as possible [20, 34]. It is because of this suspicion that children with a congenital arm defect are treated for this as young as possible; to learn to live with a prosthesis as natural as possible. Fitting for the first time after 2 years of age seems to be related with a higher rejection rate [40]. Researcher Biddiss makes a very similar statement, applying on both congenital and acquired limb absences [3].

In general the rejection rates for prostheses are very high. Over all 40 to 60% of prosthesis wearers stop using their prosthesis for activities of daily life, vocation and leisure. And an astonishing 20 to 40% stops using their prosthesis completely, which leaves a full time-users percentage of only 0 to 40% [36].

The highest peak of abandonment comes shortly after receiving the prosthesis. Due to internet, movies [57] (e.g. Star Wars both, Star Trek, Robocop, Inspector Gadget and Iron Man) and other media, the impression is often given that artificial arms and legs are as good as the original limbs, with which people can carry on every routine in their daily lives (figure 12). This misinformation makes it difficult for the prosthesis to live up to the high expectations, while it can be quite easily avoided by better information provision [3, 36, 34]. Wearing a prosthesis does make you look different, you need to learn and train to work with your prosthesis, and you will likely have to adapt your whole life to it. If people are well prepared for this new situation, they can better adapt to it.

Another rejection peak occurs when children hit puberty, sometimes after having worn the prosthesis for as long as 13,5 years [3, 35]. In puberty, appearance and fashion suddenly become much more important, for instance when attending a new school or sports club (figure 13). Children can be very honest, direct and even cruel in their opinion and criticism. Insecurity already is an issue for every teen even when there is no reason for it at all, but when you wear a prosthesis the criticism seems believable, and children are easily convinced [40].

In general, peers are of central importance in early adolescents' academic development, social functioning and psychological well-being. Peer acceptance correlates to adolescents' well-being, whereas peer rejection has been found to forecast adjustment problems in later adolescence and adulthood. Studies have shown that anxiety can be a predictor for peer rejection - for boys more significant than for girls - for instance the anxious behaviour that is due to wearing a prosthesis [32].

A persons positive or negative feelings towards his body are not only important for peer acceptation, but also affect his own well-being. The more a person accepts his body, the more secure and free from anxiety he feels. The body image is one's psychological picture of the physical self, and it can extend beyond the physical boundaries of the body to include external objects like clothing or prosthetics.

Disabled people manifest different personality factors than abled people, like increased anxiety, increased depression and impaired self-concept. Whether congenital and traumatic amputees would have a different acceptance of their disability remains disputed. Breakey concludes that there is little evidence that the age of onset is correlated with psychological adjustment [5], whereas Wagner states that children with a congenital deficiency have no sense of loss and develop compensatory skills for bimanual tasks [54].

Figure 13: When children reach puberty they become more sensitive about their body image; their physical appearance towards their social peers. And a prosthesis can be perceived as a hindrance in this process.

A research by Biddiss amongst 242 participants of all ages with any upper extremity defect in Canada, the United States and the Netherlands gives more insights in the rejection of prosthetics [3]. The majority of the participants (54%) had a transradial amputation. Of the individuals with an acquired limb absence, 54% lost their dominant hand. These rates are reflective for the amputee diversity in the western world.

The research shows the rejection rate for various occupation statuses (figure 14), in which students score very high with a 41% rejection rate. This is a doubling of the rate for children not of school age and from full time workers, which are only 20%.

Participants were asked to rate the 14 preselected categories on importance in the decision not to wear a prosthesis. 70% of non-wearers choose to answer the 'appearance category' with a significance rating of 1 (where 0 is not at all a factor, and 3 means most important factor). 33% of frequent wearers also considered appearance a factor with a significance rating of 1 [3]. This result shows that many people consider aesthetics important, but not necessarily a hindrance to stop wearing their prosthesis. It is considered a surmountable pity, a necessary evil.

Biddiss concludes that prosthesis non-use may be a lifestyle choice, but it may also result from other medical conditions that preempt prosthesis fitting, or it may be the consequence of external factors like financing or availability. These lifestyle choices have to deal with age, culture and occupation of the participants [3].

A research by Wagner amongst 489 Canadian and American prosthesis users aged between 2 and 19 years and their parents, tries to pinpoint the exact reasons of prosthesis abandonment for children. Of the 489 forearm amputees, 137 (28%) stopped wearing their prosthesis and 31 (6%) never even started wearing one.

More than a third did not wear a prosthesis (anymore), and they were asked for their reasons for rejection. There were eight response options available, including 'other' and a space for comments (figure 15) [54].

Function and comfort are the two main reasons to not wear a prosthesis; respectively 53% and 49% submitted an answer in this category. The third reason is aesthetics, mentioned by 23% of the participants. This includes the wearer's opinion, their parents' and also their peer's with regard to teasing [54].

A participant replied: "It's difficult to go to school and be just a normal kid" [54]

All in all, a child will wear a prosthesis only if it is useful; if the prosthesis is not functional, the prosthesis will be discarded. However, what is exactly perceived as 'useful' differs per individual [20, 54].

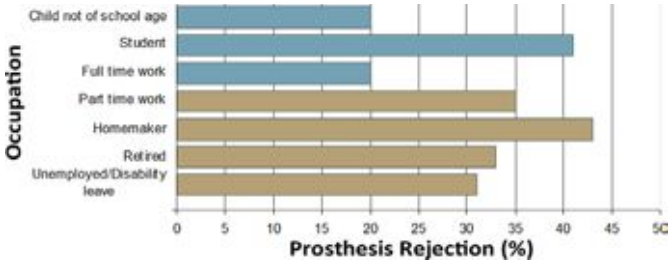

Figure 14: The table shows the prosthesis rejection for different occupation statuses. The blue bars show 'child not of school age', 'student' and 'full time work'.

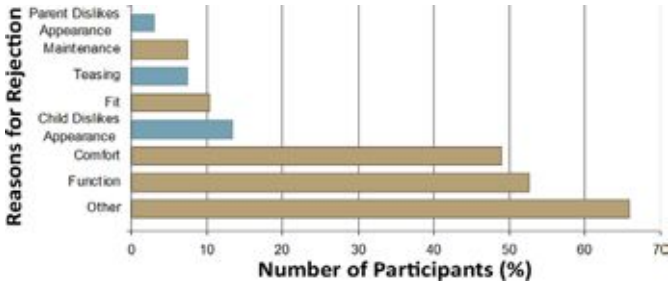

Figure 15: The table shows the number of participants and their reasons for abandonment. The blue bars show the aesthetic reasons for parents, peers and wearers.

Figure 16: Glasses products that addresses a disability, yet with little or no social stigma attached to it. This positive image for disability has been achieved without any invisibility.

INTRODUCTION

CURRENT TRENDS

Nowadays the times have changed, and differences between people are no longer disadvantages but merely qualities that can make a person unique. Personal appearance and physical beauty are becoming increasingly important, and enter into the field of medicine and health care. A new era unveils, where also prostheses can be used to create an own identity and to distinguish oneself from the mass [1, 4, 21, 22].

In his book 'Design meets Disability', Pullin describes the shift from a medical model to a social model for prosthetics design very clear. He states that the priority for design for disability has traditionally focused on enabling, while attracting as little attention as possible. This causes medical looking devices to be moulded from pink plastics in an attempt to camouflage them against the skin. He rightly asks himself "But is there a danger that this might send out a signal that disability is after all something to be ashamed of?" Contemplating about this, it could very well be that this stigma has become a vicious circle in which disabled people will never truly become abled [4, 41].

Graham Pullin: "People are disabled by the society they live in, not directly by their impairment"

Fashion can be seen as the opposite from design for disability, since it is mainly concerned with making the wearer look good to others and feel better about themselves, all with visible and sometimes even provocative means. Eyewear is a good example where design for disability has gradually turned into a visual fashion statement (figure 16), to a point where a fifth of glasses from some brands are purchased by people without visibility impairment. Even in spite of all the contact lenses that are on the market, and next to permanent medical sight restoring treatments [41].

Hearing aids are also mentioned for a future where human ability is surpassed, not just restored, and the design can play and important role in expressing these augmented capabilities.

Graham Pullin: "Glasses have become an aspiration rather than a humiliation"

Naturally, the reality is not simply black and white. Eyewear and hearing aids are worn on the body to correct the remaining bodily functions; one can easily change glasses or even remove them. Whereas prosthetics actually are an addition to replace missing parts of the body. In some way it is the body itself that is redesigned [41].

New glasses are purchased easily and frequently, simply to change appearances, like a change in haircut or a new outfit. Those very extreme and brightly coloured designs do exist, but they will always be a minority taste. However the principle that discretion is always the best policy has been shaken, and opportunities arise in the middle ground between those two extremes of bright coloured cultural designs and the flesh coloured camouflage attempts [41].

Figure 20: The dental training robot called 'Hanako', that would not suit ill in any modern horror movie.

Artificialness

The shift to less humanly prosthetics can furthermore be explained according to the 'uncanny valley' hypothesis by roboticist Masahiro Mori (figure 17). His theory holds that when robots look and act more like humans, people become increasingly positive and empathic with it (figure 19), until a certain point beyond which the response quickly becomes that of strong revulsion (figure 18). This point is reached when robots look so much like humans that they will also be judged according to human standards (figure 20), which they can not live up to. As the appearance and motion continue to become less distinguishable from a human being, the emotional response becomes positive again, and approaches human-to-human empathy levels [56]. The uncanny valley theory is very difficult to proof conclusively, nevertheless the controversial theory is accepted and applied in the fields of humanoid robotics, computer graphics and films [18].

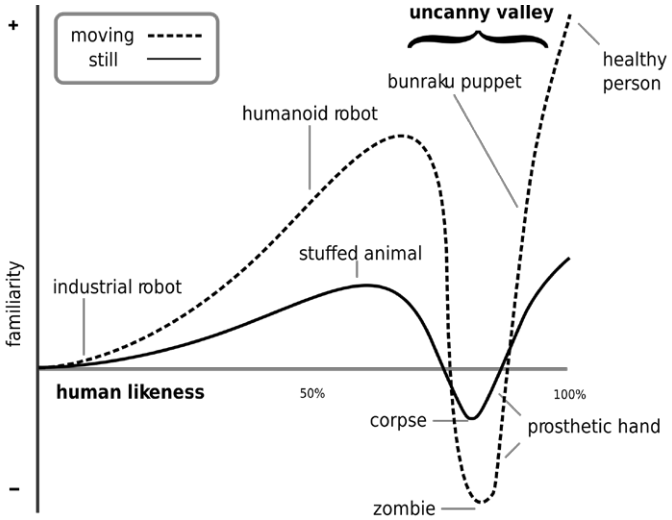

Figure 17: The uncanny valley appears in a curve of the emotional response towards human likeness. The graph shows how people react positive when robots become more humanly, but when they become too humanly there is a sudden drop to revulsion.

Figure 18: The uncanny valley can already apply to small parts of a human body, like eyes and teeth.

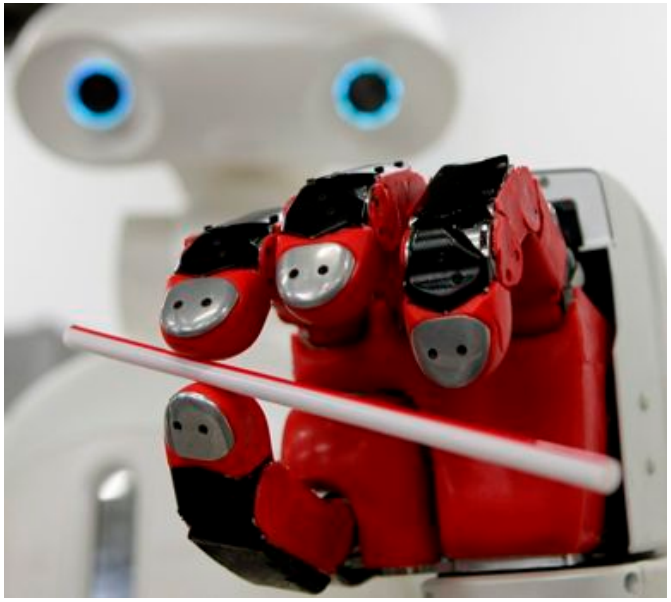

Figure 19: The uncanny valley can be avoided by creating a less humanly appearance.

Figure 23: An artist impression of a transhuman future, inspired by the famous painting in the Sistine Chapel 'Creation of Adam' by Michelangelo.

According to Gee, concealing the artificialness of objects is the source for most adverse reactions, [18] and this finding can also be applied to the field of prosthetics. Objects will be judged based on comparisons with similar items, so if prosthetics try to mimic a real arm they will be compared to and judged like a real arm (figure 21). On the other hand, when prosthetics are made to look like prosthetics, they will be judged like prosthetics. He also argues that people will accept more realistic designs if it is beneficial for them to do so [18].

The technological developments in prosthetics are by no means far enough to adequately mimic human hand motions, while the appearance of a hand can be made very realistic (figure 22). For instance with aesthetic prosthetics where the appearance is much more humanly than its motions, this makes the prosthesis look 'dead' rather than 'real'.

Ideal would be to have an appearance that fits the motion; an object that meets people's expectations, like the split-hook prosthesis does. Its appearance evokes expectations that fit very well with its motion and function in reality.

Furthermore, Mori's theory deals with appearance and motion as the only two factors defining the uncanny valley, while there might be other factors to consider that may enhance of reduce the depth of the valley, like size, age, habituation, culture and religion [18].

In future prospect, it is argued that the uncanny valley effect will also occur when humans begin modifying themselves with transhuman enhancements (figure 23) [56]. When prosthetics become perfect in mimicking motion and appearance, it is only a very small step to creating prosthetics that not only mimic one's abilities but enhance them. When this happens it is very likely that the uncanny valley effect will occur, making the prosthetics frightening and awkward again.

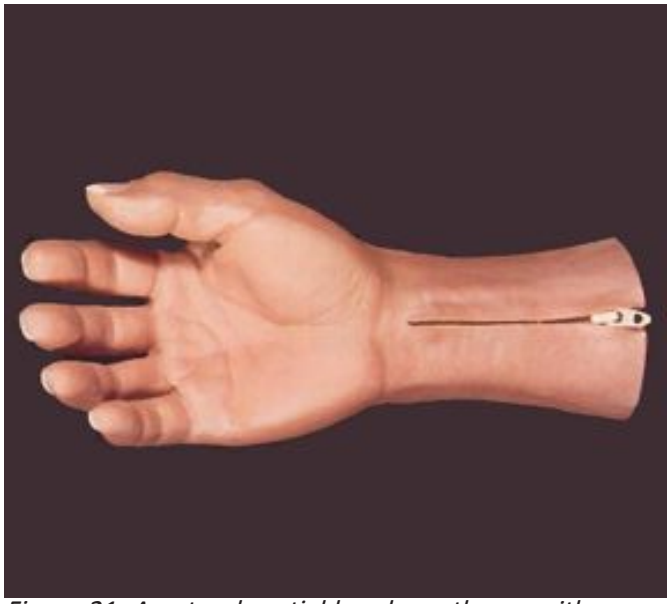

Figure 21: A natural partial hand prostheses with a very unnatural zipper.

Figure 22: Robotic arms that are made to look like real arms will be judged like real arms, and the functionality will evidently disappoint.

Figure 25: Athlete Sarah Reinertsen became the first disabled athlete to complete the Ironman Triathlon, an extreme race over 226 km.

Paralympics

Recent developments in the acceptation of disabled people have lead to a boost of positive interest in the Paralympics (for physical disabilities) and Special Olympics (for intellectual disabilities). One major positive influence was the fuss about a double leg amputee who almost qualified for the (abled) Olympics. A huge debate started about the spring-like leg prosthetics that Oscar Pistorius was using, since they were suspected to be beneficial above normal legs (figure 24). Scientific tests indeed showed that they were more energy efficient than normal legs, and they have other advantages like the absence of muscle acidification and other injuries [7]. Eventually he was allowed to participate if he qualified, which he unfortunately did not. But the 'damage' was done, and a lot of positive interest about these leg prostheses and prosthetics in general was spread.

Figure 24: Oscar Pistorius with his futuristic prostheses. Instead of resembling human legs, these prostheses were designed to imitate far more efficient Cheetah legs.

There are much more inspiring stories of famous disabled athletes, all putting prosthetics in a positive daylight. Like climber Hugh Herr, runner and model Aimee Mullins and runner Sarah Reinertsen (figure 25), who all happen to have a leg defect resulting in the use of one or two leg prostheses. The above mentioned athletes became famous for using advanced leg prosthetics that were supposedly beneficial from normal legs, like the carbon fibre 'Cheetah' Flex Foot prosthesis from the company Össur, which was tested already during the 1990s and is still being further developed.

As guest speaker in TED Talks in February 2009, Aimee Mullins describes the current trends perfectly. Prosthetics are no longer just about overcoming deficiencies, but more and more about architecting your own body and forming your own unique identity [21, 22, 29, 30].

Aimee Mullins: "I started to move away from the need to replicate 'humanness' as the only aesthetic ideal. And just like that, I went from being a disabled, to somebody who has the potential of being 'super-abled'!"

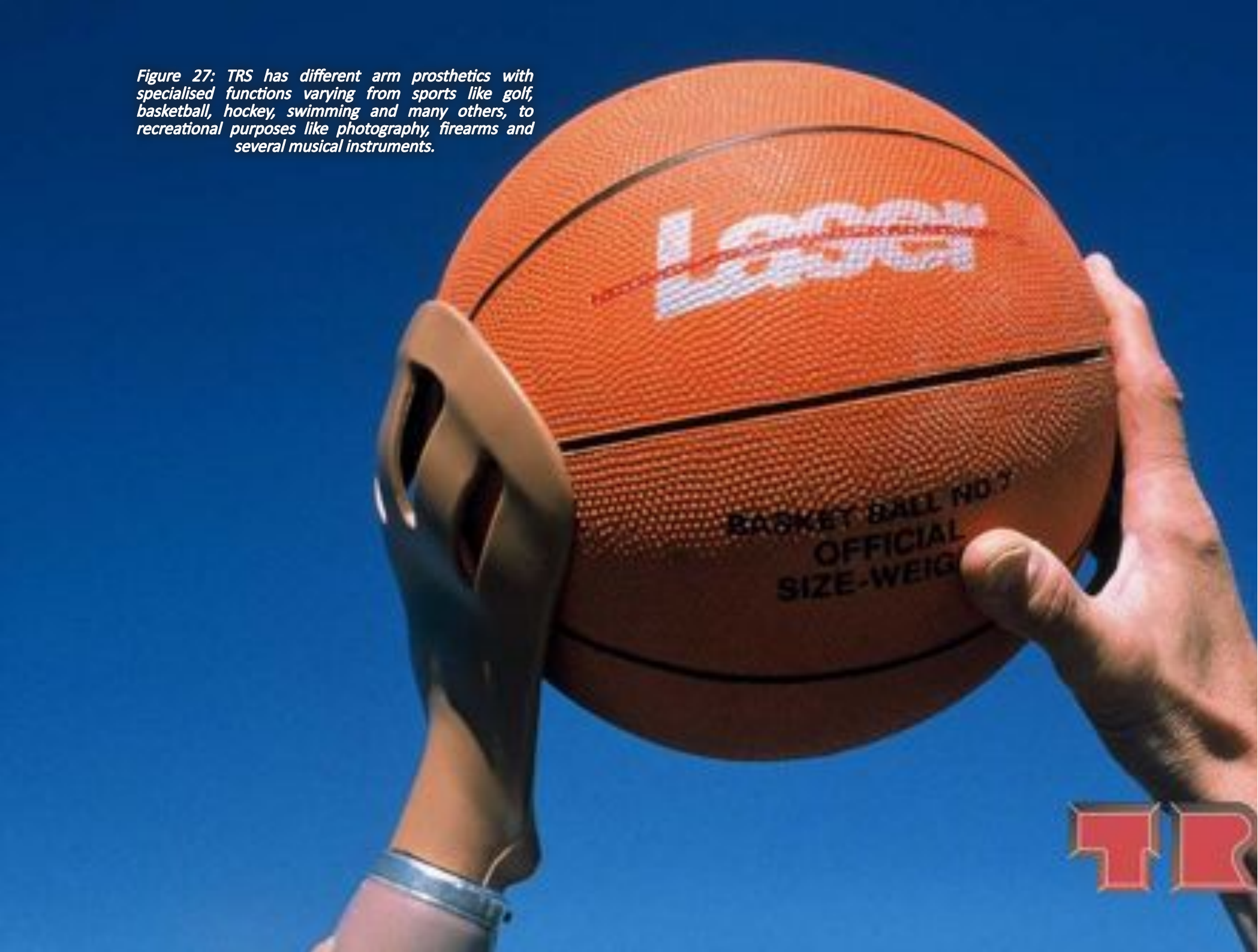

Figure 27: TRS has different arm prosthetics with specialised functions varying from sports like golf, basketball, hockey, swimming and many others, to recreational purposes like photography, firearms and several musical instruments.

The development for less humanly prosthetics has already touched upon the market for prosthetic legs, of which the Otto Bock C-Leg is a good example (Figure 26). And this trend is likely to extend its influence in prosthetic development in general in the near future.

In the area of arm prosthetics, field expert Bob Radocy already introduced some inspiring designs over the past few years, likely to be introduced in the upcoming Paralympics of 2010 and 2012. His company TRS is specialising in the field of arm prosthetics for professional sports and recreational purposes (figure 27). Similar to the Cheetah Flex Foot, their arm prostheses are not really functional for every day life, but merely focus on improving one specific motion or function. Prosthetics have become a functional 'stump-extension' rather than an actual 'limb-replacement' [15, 42].

Figure 26: The new-fashioned C-Leg by Otto Bock claims to be the new standard in knee prosthetics.

Gadgets

Another research by Biddiss [1] briefly addressed the topic of future prosthetic improvements, for instance by adding gadgets. From the 242 participants, 60% indicated that they would be interested in gadgets that make prosthetics more fun, with functions like a flashlight, mp3 player, watch and cell phone. However, in reality the interest for gadgets still remains subordinate to true improvements in function and comfort.

One example is the 'Reverb Arm' of Advanced Arm Dynamics that was custom designed with the purpose of always having music around (figure 28) [15].

Figure 28: The Reverb Arm has an iPod and speakers inserted in a reverb cavity in the prosthesis.

In this same category, Finnish software developer Jerry Jalava lost half of his middle finger in a motor accident. Together with his surgeon, he came up with a prosthetic finger with build-in memory (figure 29) [44].

Figure 29: Software developer Jerry Jalava developed his own detachable 'USB-finger'.

Figure 30a-d: Four state of the art bionic hands. The Touch Bionics Prodigits (a) and I-Limb Pulse (c), the RSLSteeper BeBionic (b) and the Otto Bock Michelangelo (d).

Bionic hands

One of the latest trends is the development of so called bionic hand prostheses, a very attractive and promising term. Even in the small global market of arm prosthetics, several companies launched their bionic hand in the first part of 2010 (figure 30) .

- ProDigits (a) and I-Limb Pulse (c) by Touch Bionics
- BeBionic (b) by RSL Steeper
- Michelangelo (d) by Otto Bock

The characteristics for bionic hands is that they have 4 digits and a thumb, all capable of moving. Due to its mechanical complexity, bionic hands are electrical powered and Myo-electrical driven. The hand is still very mechanical looking, and the natural appearance has to be simulated by a cosmetic glove [17].

Despite all the good efforts to promote their prosthetics as being better than a normal hand [17, 28], the fact remains that these prosthetics have to be constantly monitored by the user in order to see what they are doing. There is no feedback, and thus no sub-conscious control of prostheses [36].

Critical reader Rolf Schweitzer (figure 39) describes it as follows. With a price of several ten thousands of Euros, the new bionic hands cost about the same as a state of the art laptop, desktop, car and drill hammer together. And for that money, he would like a product that functions at least as good as those products combined [46]. He furthermore argues the obvious discrepancy between the feelings of the wearer, and the feelings of the viewers.

Schweitzer: "From a distance, the bionic hand looked artificial, stiff, slow, performed extremely loudly and appeared to me rather annoying. Yet, operating it myself sucked me into a dream world of simulated hand function that I viewed entirely differently and it put a wide smile on my face." [46]

Figure 31: As conceptual working principle, the Immaculate is a neurological prosthetic that will be connected to a user's central nervous system. Each joint is a globe joint, allowing a larger freedom of movement than a normal human arm.

INTRODUCTION

ART AND AESTHETICS

Many of the previous mentioned developments have to deal with improving the functionality as a main focus, and they change the prosthetic aesthetics merely as a side effect. This is mainly caused by the composition of the companies that develop prosthetics; they barely involve any industrial or interaction designers [41].

However, there have been (private) projects focused entirely on the aesthetic values of prosthetics, most of them with an artistic or consumer background. The WILMER Appealing Prehensor was already mentioned [34, 35], but there are more form study-like projects done since the 1990s.

Immaculate [14]

A famous example is the 'Immaculate' from Hans Huseklepp, who believes that prosthesis should go beyond mere functionality and become objects of fashion and identity (figure 31).

Eames-Inspired Prosthetic Leg [19]

Another interesting example is the 'Eames-Inspired Prosthetic Leg', created by industrial designer Joanna Hawley (figure 32). The question if users would consider this a beautiful prosthesis is not answered, but the project definitely conveys a completely different design approach.

Super Prosthesis Project [39]

The Super Prosthesis Project is entirely dedicated to the new trend of exploring 'armwear' as an object of empowerment, choice and identity (figure 33).

Figure 32: Joanna Hawley decided to design a leg prosthesis based on the Eameses design style, characterised by the use of wood. She used 3D laser scanning to create a CAD model, with which a functional wooden prosthesis could be designed.

Figure 33: At the Royal Collage of Art in London, artist Becky Pilditch works together with prosthesis user Holly Franklin to create appealing and evoking designs for her prosthesis.

Figure 34: The Nike Prosthetic Project shows the effect of branding with a powerful brand like Nike.

Nike Prosthetic Project [27]

A project by Colin Matsco in cooperation with Nike. The leg prosthesis is aimed at young urban male athletes, and needs to have an appearance suitable for such a target group. Modern production techniques like 3D printing are combined with a powerful sports brand like Nike (figure 34 and 35).

Swimming Prosthetic Leg [53]

Designer Chris Vella analysed the current available leg prosthetics, and noticed a void for swimming products. He designed his swimming prosthesis with help of disabled athletes, focusing very much on mimicking and enhancing the motions of a normal swimming leg (figure 36).

Figure 35: The Nike Prosthetic Project only mimics a real leg in shape, size and function, while the appearance is purposely made very futuristic and sporty.

Figure 36: The swimming prosthetic is a typical example of form follows function, whereas the design is based upon the natural swimming motion of the leg. It too has a very futuristic and sporty appearance.

Figure 39: Wolf Schweitzer about his red prosthesis experiment: "With the standard cosmetic Otto Bock prosthesis some kids would get really scared and some adults would get really nervous. The hook was OK but did not offer any emotional ease for the innocent bystander. With the red Becker hand, the same kids now felt relaxed enough to touch it and to comment on it freely. Even one adult laughed and immediately grabbed it when she saw it, very positive. This hand looks and feels approachable while offering an unprecedented degree of functionality."

Personalisation

Not only professional designers try to improve prostheses, the users themselves also try and make the best of it [1]. With the available means, they personalised their prosthesis by making enhancements in the appearance (figure 37). The reasons to change their prosthesis are diverse, but all focused on the urge to change the standard stigmatising design.

Figure 37: Real life attempts of people to personalise their own prosthesis. The images were downloaded from public photo community www.flickr.com.

Red Arm [47]

Wolf Schweitzer lost the lower part of his right arm in 2007 at the age of 40. Fortuitously he also had a bit of design engineering background, which caused him to be a field expert in using a prosthesis after having a traumatic arm defect, as well as a professional designer. His life experiences have caused him to make some pretty harsh negative statements about the current level of prosthetic developments. This lead him to a continuous search for 'the best' look for his own arm prosthesis (figure 39).

Schweitzer: "I realized that cosmetic standard prostheses made people nervous and responding to me in stereotypical distressing ways"

Figure 41: Prosthesis sockets as a canvas for astonishing artwork by artist Mark Dalton from GTOPI.

SleeveArt [1, 4, 33]

SleeveArt is the inspiring story of Fred Pauloz, a leg amputee since 1984. To solve his problem of cosmetic sleeves that quickly wore off, he developed apparel sleeves for his prosthesis. Fred got such overwhelming positive responses to his colourful sleeves (figure 38), that he started his own small business *Fred's Legs* in 1999. The feedback he gets from satisfied customers through the web-shop is equally enthusiastic.

Elizabeth: "Self esteem/body image issues loom large at the moment for me, as I'm sure with many amps. Your sleeves have made this bad pill easier to swallow." (SleeveArt feedback)

Figure 38: Several prosthesis users wearing SleeveArt.

With new techniques, spandex 'sleeves' can easily be laminated onto the socket, making it a more permanent and wear proof decoration (figure 40).

Becky: "My prosthetist finished laminating my socket a couple of weeks ago, and I just can't stop admiring the design. I originally did not want the socket laminated, but later grew to hate the flesh-tone of my prosthesis. So, thank you for such a wonderful service you provide to us amputees. Now people really have something to look at" (SleeveArt feedback)

Global Tattoo Orthotic Prosthetic Innovations [4, 25]

Another branch of industry is taken care of by GTOPI, a company founded by amputee Dan Horkey in 2008. GTOPI is specialised in professional paint jobs for prosthetic sockets, and this includes custom airbrushed tattoos. His work is truly astonishing (figure 41), but with a price tag of hundreds to thousands of dollars for a custom paint job, it remains a very exclusive solution.

Figure 40: A prosthesis with SleeveArt before and after laminating.

Figure 42: The Sint Maartenskliniek in Nijmegen is a specialised orthepedic clinic. It is one of the few clinics in The Netherlands with its own revalidation team for children's arm prosthetics.

Figure 44a: Stillframe from 'The Klokhuis' shows how plaster is put on the stump.

INTRODUCTION

GETTING A PROSTHESIS

The process of getting a prosthesis is very important, and several researchers suggest this should happen as soon and early as possible [20, 34].

The DIPO has always recommended this fitting process should be done by a team of specialists with different educational backgrounds, and thus they helped realizing such teams in rehabilitation clinics Sint Maartenskliniek in Nijmegen and De Hoogstraat in Utrecht [36].

Dr. Ir. Dick Plettenburg is not only an important member of the DIPO, he is also involved as a prosthesis councillor in these revalidation teams.

Such revalidation teams are specialised in the revalidation process after an arm deficiency. Living with a prosthesis is an important solution to deal with such a deficiency. There are specialised teams for children and for adults, since both require a slightly different approach. One difference is that (young) children often have their parents to be convinced, another issue is the physical and psychological development that complicate the revalidation process for children.

A typical revalidation team is guided by a revalidation specialist, and is completed with two therapists (a physical therapist and an ergo therapist) and two technicians (an orthopaedic instrument maker and a prosthesis expert).

The process analysis on the following pages is created through analysis of two episodes from the educational TV show 'Het Klokhuis' [23, 24] and a visit to the revalidation team in the Sint Maartenskliniek on March 19th 2010 (figure 42).

Components

In arm prosthetics, the hand-part is conceived as a separate modular component from the arm, and thus it is produced and purchased as such.

The forearm is composed of an inner and an outer socket, to compose a very personal and tailor-made product. The inner socket is custom made by an *orthopaedic instrument maker* to fit around the stump, and the outer socket is also adjusted to fit the body characteristics of the wearer. The forearm of the prosthesis usually ends at the wrist, where the hand can be assembled.

Producing the hands requires different skills and techniques, and thus this is generally not done by the prosthesis maker. The hands and hooks are available in standardised sizes through a few manufacturers, and have to be ordered separately.

Insurance [31]

In The Netherlands, legal arrangements have been made with regard to prosthetics and orthotics. The details differ per insurance company, but the most important thing is that all expenses for prosthetics will be fully covered.

This is not limited to just the absolute necessary prosthetics (cosmetic or functional), but also prosthetics with a more decorative purpose are covered.

A reference from a medical doctor is not required, and it is even possible to get a second spare prosthesis, with a different purpose.

In this prospect, it is valid to say that all prosthetics will be covered by insurance in The Netherlands. And since this medical insurance is obliged, everyone has the opportunity to try and buy a prosthesis when the situation occurs.

Figure 43: One of the pages in the informative documentation in the Sint Maartenskliniek describes the available skin colours for cosmetic gloves.

- The first step in getting a prosthesis is the referring to a specialised prosthesis team, and they can get involved already before a *scheduled* amputation. However, the fitting process can not start until the stump has been given enough time to heal.
- The amputee will be asked for his or her own expectations and preferences for a prosthesis (figure 43). This can be related to the periods of time that a prosthesis will be worn, but also during which activities. In case of young children, this decision is up to the parents. The staff can give tips and recommendations for the type of prosthesis, mainly with material and know-how that the specialists have collected themselves. But in the end the patient himself is expected to do the research and pick the prosthesis of his choice. There are a few different socket techniques and many different hands and hooks to choose from.
- The occupation of orthopaedic instrument maker is a very specialised craft that is mastered by only a few people in the Netherlands. At his workshop, a plaster imprint of the stump will be made (figure 44a and b), in which a positive plaster replica of the stump can be casted (figure 45).

Figure 44a and b: The prosthesis has to fit a stump that is unique for every person. To enable the perfect fitting, a plaster mould of the stump is created.

Figure 45: Prostheses are very personal products that have to be tailor-made for every stump. Therefore the workshop of the orthopaedic instrument maker is usually filled with plaster stumps and limbs.

- Around this plaster replica, a socket is formed (figure 46a). With a little post-processing (figure 46b), the socket will have a perfect fit with the stump. The socket is the prosthesis forearm on which any type of hand or hook can be mounted.
- The WILMER Open Fitting requires a slightly different approach, since a wire frame needs to be tailor-made around the arm of the amputee. This requires a bit more bending and welding, but eventually a stump-shaft with similar properties is acquired.
- When a child finally has a prosthesis, he or she will be scheduled for an appointment with the revalidation team every few months, depended on his or her personal situation. Children will grow, and since their prosthesis does not grow with them, it must be adapted and replaced regularly. A child that needs a new prosthesis approximately every two years is no exception.

Figure 46a and b: Still frames from 'Het Klokhuis' show how a skin coloured socket is created.

Figure 47: A man with two below knee amputations in a wheelchair awaits the softball pitch.

INTRODUCTION

EXPERT INTERVIEW

Hans Arendzen (Prof. MD.), Rehabilitation specialist

Also see appendix L

In this analysis chapter, several assumptions were made and questions have risen. The purpose of this interview was to get the opinion of an independent expert regarding the conclusions and assumptions following from the analysis chapter of the report.

The interview was held with revalidation specialist Hans Arendzen, professor at the *Leiden University Medical Centre* (LUMC), and associate of the *Rijnlands Revalidation Clinic*. A transcript of the interview can be found in the appendices.

Professor Arendzen has been working with arm and leg defects for several decades. But since several years he is solely focussing on leg defects, redirecting 'the arms' to a specialised centre nearby.

Differences between limbs

Arendzen confirms that the market for arm prosthetics is much smaller than for leg prosthetics. He estimates that there are not even a hundred arm amputations annually, against thousands of leg amputations.

The most important difference is that a leg prosthesis is always indisputably functional (figure 49); whether it is a cosmetic prosthesis or not, a leg prosthesis is always designed to stand and walk with.

Arendzen: "A leg prosthesis is by definition a functional prosthesis. Because if you don't have one, you'll be in a wheelchair." (L)

Two opposing categories

Arendzen acknowledges that function and cosmesis still do not match, which might be an interesting design opportunity. This results in two opposing groups of prosthesis wearers. Firstly there is the group of people who want to camouflage their defect. They often choose an inconspicuous cosmetic prosthesis and do whatever it takes to look as natural as possible.

And secondly the people who accept their body with all its flaws and unique characteristics, and they want others to do the same. They try to get as much functionality in spite of their defect, and therefore often have a functional prosthesis or no prosthesis at all. This group is growing slowly but gradually.

Arendzen: "It could be my old-fashioned mind, but I can not imagine how function and cosmesis could be combined in one design. On the one hand concealing, and on the other hand... 'Wham!'" (L)

This dichotomy exists for all the groups that are involved with prosthetics.

Every parent wants their children to develop as good as possible. Parents often have problems with dealing with the arm defect of their child and look for a camouflaging solution. But there is also a small group that accepts the defect of their child, and they want to give their kids as much functionality and opportunity as possible with a functional solution.

Parents can decide the initial steps for a prosthesis for their kids, but it is the child that needs to commit to the prosthesis, to go wear and use it. So ultimately it is always the child who decides.

These same issues recur when the child becomes self-aware in puberty. Teenagers can feel rejected by their peers because of their prosthesis, which will affect their self-image and self-confidence. Most of the children do not want to be different from their peers. They will try to cover and camouflage their defect with a cosmetic prosthesis. But there is also a small but increasing group that has the self-confidence to dare to be accepted for who they are.

FIgure 48: Two hands are often required for complex tasks that involve buttons and keys on electronic devices.

Functionality

The trend for less humanly prosthesis revealed itself already over 20 years ago in the USA, when American developers did not attempt to disguise their prosthetics like limbs anymore. They felt that a prosthesis was something to show, and something that needed to be functional above all. They design for a specific but increasing group of users who do not want to pretend anymore, with conspicuous functional prosthetics. The products can even be a little crazy and extrovert.

Arendzen describes the growing group of functional prosthesis wearers: "This is my constitution, this is who I am. But I'm making the best of it, and you'll have to accept me for who I am!" (L)

An important aspect of functionality is tactile feedback. A prosthesis is a dead thing, and the lack of feedback is a problem that sometimes even leads to rejection. When tactile feedback lacks it has to be compensated, for instance with visual feedback. This causes the prosthesis wearer to always concentrate on and think about his actions.

On the other hand there is only a very small share of tasks that really need two hands. Most of the tasks can be performed single-handed, with or without a supporting hand or stump, and especially children are naturally very inventive in this.

Tasks that need two hands can be divided into the handling of heavy objects, and the performing of complex tasks. Handling heavy objects used to be important for heavy labour and physical jobs. But in this digital age complex tasks have become increasingly important. Operating buttons and keyboards might occasionally be performed single-handed, but this is significantly less convenient (speed, accuracy) than ambidextrous handling (figure 48). These skills are not only important in operating devices for ADL (electronic devices like a camera and a remote control), but might also be important for education (internet), work (typing), hobbies (computer games) and social life (phone, instant messaging).

Future appearance

There is not one single solution that fits everybody, it is all about individual choices. Nowadays there is the choice between function and cosmesis, while people might be interested in a more grey solution.

Cosmetic prosthesis lack functionality, while functional prosthesis often suffer from bad associations from the past. A prosthetic hook is still associated with Captain Hook, the villain in Peter Pan. The WILMER Appealing Prehensor tries to improve the image of arm prosthetics, but everyone still thinks its a hook.

Arendzen concludes that something substantial might be changed in the perception of functional prosthetics. Times have changed, so is the current shape of the functional hook prostheses still the most logical solution?

Arendzen about current arm prosthetics: "But is this still the most suitable shape for performing two-handed tasks?" (L)

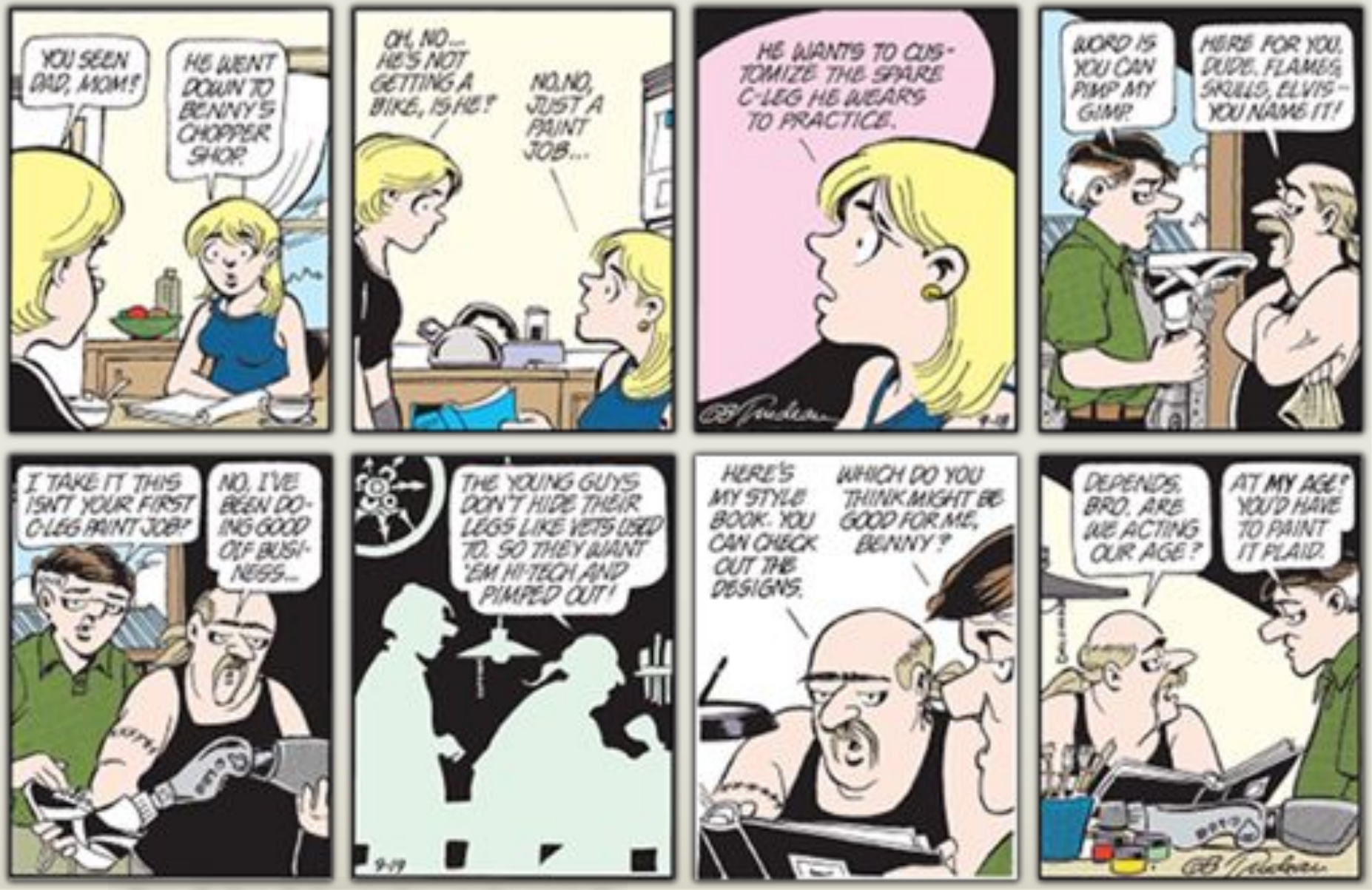

Figure 49: Garry Trudeau touches a tender spot in his Boston Globe comic Doonesbury. The story is about B.D. who suffered a leg amputation, and now wants to personalise one of his prostheses.

INTRODUCTION
CONCLUSIONS

In The Netherlands, about 3750 people have an arm prosthesis [51], but the rejection rate is astonishing. 40 to 60% of prosthesis wearers stop using their prosthesis for activities of daily life, vocation and leisure. And 20 to 40% stops using their prosthesis completely [36].

The highest peak of abandonment comes shortly after receiving the prosthesis. Due to internet, movies and other media, the impression is given that technology is very advanced and artificial arms and legs are as good as the original limbs. This misinformation makes it difficult for prostheses to live up to the high expectations, while it can be quite easily avoided by better information provision [3, 36, 34].

Another rejection peak occurs when children hit puberty, even after having worn the prosthesis for as long as 13,5 years [3, 35]. In puberty, appearance and fashion suddenly become of increased importance, for instance when attending a new school [3]. Children can be very honest, direct and even cruel in their opinion and criticism. Insecurity already is an issue for every teen even when there is no reason for it at all, but when you wear a prosthesis the criticism seems credible, and children are easily convinced [32, 40].

Since the existence of arm prosthetics, prostheses have been trying to mimic normal human morphology, in function as well as in appearance [41]. Exceptions have been made, like the split-hook prosthesis in 1912. And it is striking to see that this prosthesis still proves to be one of the most functional prostheses available [36]. Following the developments in glasses [41], current trends show a movement in the appearance of prosthetics, from 'as humanly as possible' to 'a personal fashion statement' [21, 22, 29, 30]. Also the functionality could be expanded beyond to those from a normal human arm [1].

Several sources indicate that prosthetics with a humanly appearance might not be the best solution, or at least not the only possible solution [18, 34, 35, 41, 47]. Prosthesis wearer Wolf Schweitzer observes:

"With the standard cosmetic prosthesis kids and adults can really get nervous and scared. The split-hook was already better but still did not offer any emotional ease for the innocent bystander."

The image and appearance of the prosthesis seems to be of great importance for the acceptation and appreciation of the prosthesis, for the user as well as his social environment [20, 54]. There are two main types of arm prostheses; functional and cosmetic, which makes a prosthesis either beautiful or useful, and the choice for just one of those qualities is a rather cruel one to make [25, 41].

Many of the current research efforts focus on improving the technology behind cosmetic prostheses, but they neglect aesthetical aspects and emotions in the process [41]. Furthermore this type of research is valuable and does not provide any short term solutions [36].

There is a need for refreshingly new prosthetics [22, 35, 41] (figure 32), and several private projects from prosthesis wearers show the benefit and feasibility of making prosthetics more appealing [14, 15, 19, 27, 39, 47]. After all, appearance remains the first thing anyone judges or is judged upon [15, 21, 22, 41].

INTRODUCTION
DESIGN ASSIGNMENT

Create an emotion-driven redesign for a functional and fashionable lower arm prosthesis for early adolescents.

Figure 50: The wearer of this prosthesis clearly saw the stigmatising emotional value attached to prosthetic legs, and decided to exaggerate it as a statement.

CHAPTER 2: PRODUCT EMOTIONS IN ARM PROSTHETICS

THIS CHAPTER

This second chapter will narrate the first explorative study of this project. The PrEmo research into the emotions and concerns of the target group teenagers regarding prosthetics.

PrEmo is a research tool that lets participants capture their emotional experience for a product in an understandable and accessible way. Nine prostheses are compared for their strengths and weaknesses, and actual teenage prosthesis wearers are interviewed for detailed insights and concerns. This first study adds up to the concern profile, which is the concluding subchapter.

A concise concern profile reflects the target groups motivations and concerns. This profile will be a point of reference in addressing the user's appraisals, and contains the concerns of general life, usage situations and product design. The concern profile should aim to give clearance about the user's likes, goals, standards and expectations.

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Figure 51: PrEmo consists of 12 animations of a character, to represent 6 positive and 6 negative emotions. Participants are asked to identify their own mixed feelings with the expressions of this character, to assess to what amount each of the emotions is elicited by the appearance of a product.

PRODUCT EMOTION

Also see appendix A

Prosthetics are a much more personal and emotional product than ever anticipated, while this emotional side has never truly been attended.

Products can evoke feelings that are good or bad, and designers naturally strive for products that evoke good feelings, since they have all kinds of favourable effects; they are bought, talked about in a positive way, contribute to brand image and are even forgiven some design imperfections. On the other hand, products that evoke bad feelings generate disappointed users and complaints, and this still applies too often to prostheses. These feelings are an important part of emotions, and so is behaviour. Occurrence of an emotion tends to result into a specific behaviour. For instance, angry people shout and fight while sad people fall silent and withdraw [13].

In other words; products evoke feelings and emotions that can affect unconscious behaviour. It would be very useful if we can apply this theory to the field of prosthetics, where people generally have negative feelings associated with prostheses. An emotion-driven redesign for an arm prosthesis for adolescents seems appropriate and even logical.

Desmet: "Ignoring the emotional side of product experience would be like denying that these products are designed, bought, and used by humans."

PrEmo

Several methods have been developed and explored to make emotional design more tangible and provable [8, 10, 12]. They all deal with having the target group quantify their emotions and qualify their appraisals towards existing or new products. The findings were used to develop a tool that allows participants to describe their emotions towards a product in an unambiguous and unconscious way; 'PrEmo', short for Product Emotion Measurement instrument.

PrEmo has been developed as a nonverbal self-report instrument, to measure specifically emotions evoked by product designs. Instead of using words, respondents can report their emotions with the use of expressive animations. Six pleasant and six unpleasant emotions are measured that are often elicited by product design (figure 51). PrEmo is a computerised tool that can be used in online questionnaires. [10, 48].

In practice, products can be compared for instance by using images. Then for each product, the participant is asked to indicate how well each of the emotion animations fits to his feelings. For each research, a maximum of 8 products or stimuli can be compared.

Several project have already shown the value of this new tool in product emotions [10, 12], but the fact that it is now being commercially exploited speaks volumes [48].

Figure 52: The participants in this research consist of three groups; teenage prosthesis wearers, their teenage peers and the prosthetics professionals like revalidation doctors, therapists and prosthesis makers.

STUDY 1: ANALYSIS

General Setup

The first chapter showed the large number of prosthesis rejection, especially amongst teenagers. The goal of this study is to get insights into the emotional values and the underlying concerns that adolescent arm prosthesis wearers and their teenage peers have towards the available arm prosthetics as well as some futuristic design projects. Each participant will be asked for their response towards images of several arm prostheses with diverging characteristics.

This first part of study 1 will focus on capturing the emotions that the involved user groups feel towards different prosthetics. The products will be compared with the PrEmo tool through an online questionnaire, with courtesy of the SusaGroup.

Since emotions result from appraisals, the second part will focus on getting insights on the users' concerns and the corresponding product characteristics.

Participants

The participants will consist of three groups of people with different interests towards prosthetics (figure 52). The prosthesis wearers themselves, who are 'scarce' and hard to reach. Their peers, who are easy to approach and can be used as a frame of reference. And the prosthetic therapists, who also have a lot of experience with prosthetics, and who are easier to contact. The two 'additional' groups are added for reference and latitude in the research results.

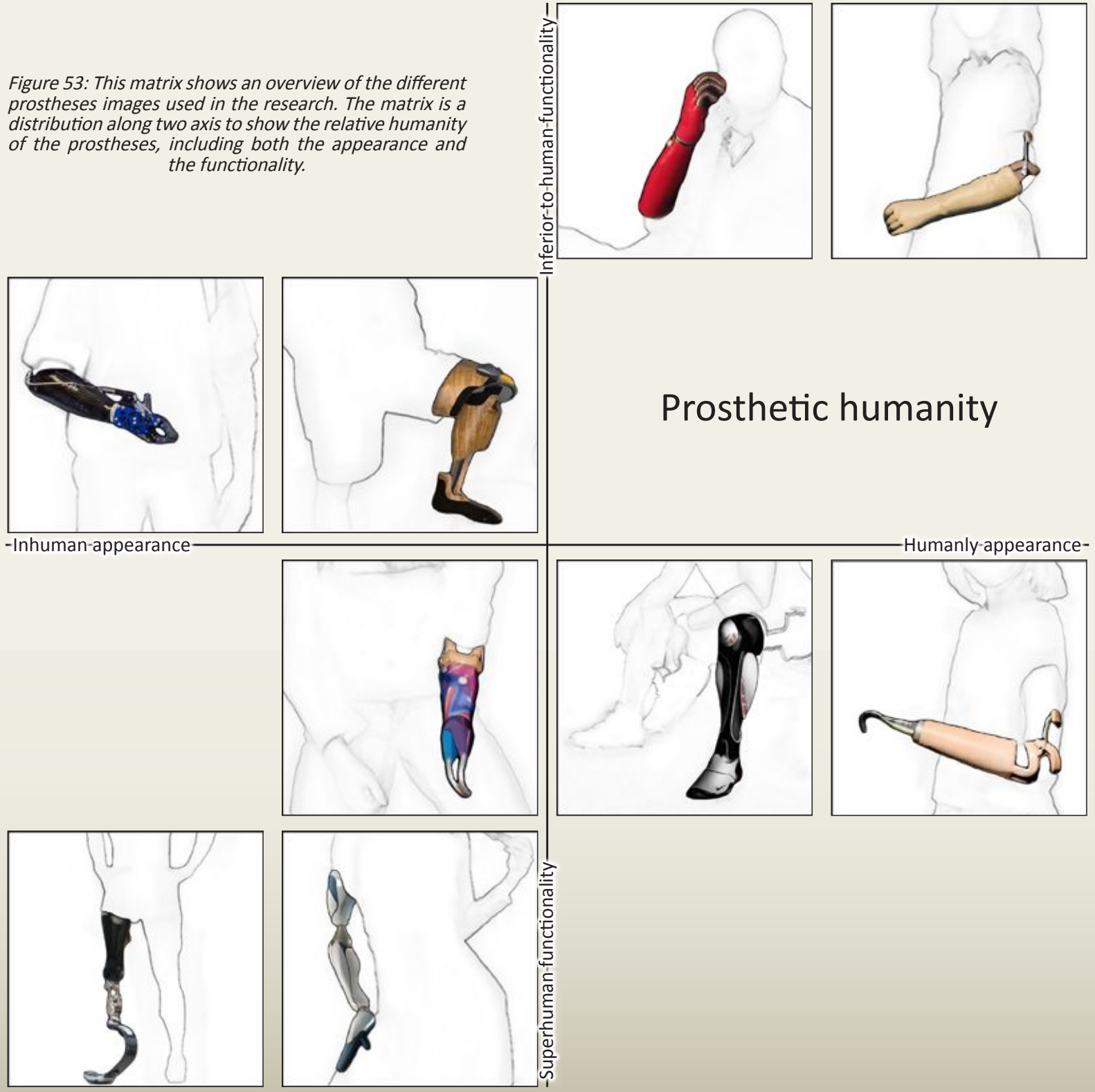
Prosthesis wearers were contacted with individual paper invitations. Rehabilitation clinic '*Sint Maartenskliniek* '*i*n Nijmegen provided the opportunity to send these invitation to suitable people in their patient pool. In addition, an invitation was published on three popular Dutch websites regarding prosthetics: '*LVvG*', '*Handvereniging*' and '*KorterMaarKrachtig*'.

Teenage peers are contacted with an open invitation on the very popular general forum '*Fok!*'. Due to disappointing numbers of participants, a secondary school in Delft was contacted. This resulted in the participation of an entire class of first year students from the '*Stanislascollege*'.

The professionals were asked personally at the '*Sint Maartenskliniek*' and the '*LUMC Hospital*'.

Most participants are teenage boys and girls in the target group of 12 to 14 years, except for the group of professionals, obviously.

Figure 53: This matrix shows an overview of the different prostheses images used in the research. The matrix is a distribution along two axis to show the relative humanity of the prostheses, including both the appearance and the functionality.



Products

The prostheses are selected for their different characteristics, resulting in differences in humanly appearance and human-like functionality (figure 53).

The prostheses are a mixture of currently available and futuristic prosthetic designs. Six arm prostheses are completed with three leg prostheses, in which the arm prosthetics can be further divided into hand-shaped and hook-shaped prostheses. Other differences can be discerned in the material, colour, shape, arm fixation and mechanical functionality.

Hand-shaped prostheses (figure 53)
1 = Cosmetic glove with WILMER© Open Fitting
2 = Becker© red hand with flexible fingers
3 = Huseklepp's Immaculate prosthesis

Hook-shaped prostheses (figure 53)
4 = Split-hook with WILMER© Open Fitting
5 = Lesa© prosthesis with carbon arm (figure 54)
6 = WILMER© Appealing Prehensor
with personalisable colours

Leg prosthetics (figure 53)
7 = Össur© Cheetah prosthesis
8 = Eames style leg prosthesis
9 = Nike© Sports leg

The prostheses are shown with one image per product. The images must be comparable in style in order to reduce biasing. Due to the limited availability of images, an image composition is chosen that shows the prosthesis in a usage situation (figure 54). To focus only on the prosthesis, the user and the background are replaced with an artistic wire-frame. This also increases the possibility to identify with this 'anybody'. Each of the images is created in a decent resolution (800x800 pixels), and shows the prosthesis semi-centered with a length of about 600 pixels.

Data

The data of the first part is visualised with a product space, and explained further with several bar graphs in combination with the summarized comments. Furthermore the data is analysed for significant values with several statistical methods in PASW Statistics 18 (formerly known as SPSS).

The obtained data in the second part will be structured according to the three levels of product attachment, which are product-focus, activity-focus and self-focus, as is described earlier in this chapter. Prosthetics are specifically products that have distinctive functionality and characteristics in each of these categories, especially when it comes to selecting a prosthesis.

Figure 54: An image of a prosthesis in the way it is presented to the participants during this research. This particular product is also the only prosthesis that has not been mentioned earlier in this report. It is a mechanical looking hook by the company Lesa.

STUDY 1: ANALYSIS

PART 1: PREMO

Research question

What emotional responses do the prosthesis wearers, their peers and their therapists have towards the presently available prostheses designs, and how does this relate to the prosthesis humanity?

Approach

In this research, the participants are shown images from diverging arm prosthetics, and are asked to record their emotional response in an online PrEmo questionnaire.

The participants will be selected in three groups, with different interests towards prosthetics; the teenage prosthesis wearers, their peers and their prosthetics professionals. The aim is to approach at least 10 participants in each interest group to obtain usable and comparable data.

The nine compared products (or stimuli) are presented in random order, and so are the emotion animations.

Results

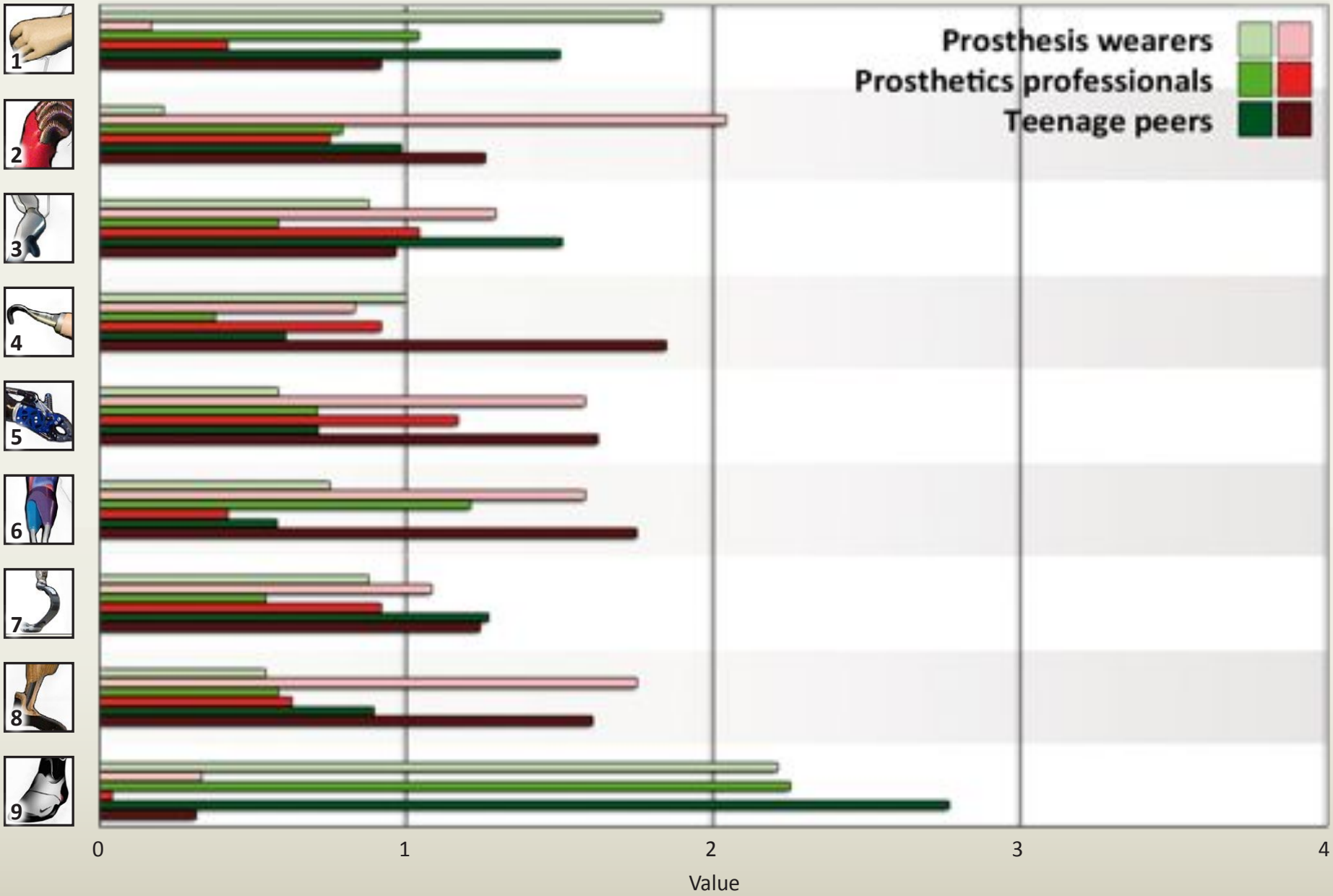
The obtained emotional data of each of the prostheses will be globally visualised in bar graphs, giving a clear view on the differences in the emotions involved. More conclusions can be drawn from the differences within each prosthesis, the three participant groups, and the differences in prosthesis humanity.

A more detailed analysis of the research data will be performed with the prostheses compared in groups of three. The three hand-shaped prostheses, the three hook-shaped prostheses and the three leg prostheses.

The data will also be visually displayed with PASW Statistics 18 (Formerly known as SPSS) in a product space. This is a two dimensional scale of the emotions, on which the products can be positioned. The position and distance show how the product is related to the different emotions.

Finally, the study will be concluded and discussed, in order to proceed to part 2 of this first study.

Figure 55: The mean scores for positive and negative emotions, compared by product and participant group. Positive emotions are shown in green, negative is red.



STUDY 1: PART 1: PREMO

RESULTS

Also see appendix B

For each prosthesis, the participants were asked to rate how well six positive and six negative emotions (figure 51) fit with the product, with a score from 0 to 4.

When looking at the data, clear differences in the emotional perception of the different prosthesis can be seen (figure 55, 56), as well as differences between the different participant groups (figure 55, 57).

- The Nike leg prosthesis (9) is one of the products that really stands out in a positive way. It is placed at the far left of the product space (figure 56), close to the positive emotions, and as far away as possible from the negative emotions. All participant groups share this opinion.
- There are only two prosthesis that evoke more positive than negative emotions for all participant groups. Next to the Nike prosthesis, the prosthesis with the Cosmetic glove (1) is the other one. This is remarkable but explicable, since these two prostheses represent the traditional prosthesis that are *'as humanly as possible'* and the new trend for *'a personal fashion statement'*. Especially the prosthesis wearers were very positive about this prosthesis, they assessed it even more positive than the Nike leg.
- The Becker red hand (2), the Split-hook (4), the Lesa hook (5), the Össur Cheetah leg (7) and the Eames style leg (8) are all prostheses that evoke more negative emotions than positive emotions amongst all participant groups.

The two other prostheses evoke a mixture of negative and positive emotions that differ between the participant groups.

- Huseklepp's Immaculate (3) is perceived negative by the wearers and the professionals, while the teenage peers were more positive.
- Another remarkable observation can be made with the WILMER Appealing Prehensor (6). The prosthetics professionals are quite positive about this prosthesis, while both the wearers and the teenage peers are distinctively negative.
- The prosthesis wearers are very clear in their emotional opinion, as can be seen with the Becker red hand (2), the Lesa hook (5) and the Eames style leg (8). The professionals and the teenage peers show positive and negative emotions for these prostheses, but the wearers are clear-cut negative.
- The adult professionals are in general more moderate with their emotions than the teenage peers and teenage prosthesis wearers. Their average scores never approach 2, except for the Nike prosthesis of course.. This can be explained by the fact that they work with prosthetics on a daily basis, and therefore do not get that exited by prostheses anymore.

In general, the hand-shaped prostheses are assessed more positive than the hook-shaped prostheses. Hand-shaped prostheses get more positive responses and fewer negative ones, of course apart from exceptions.

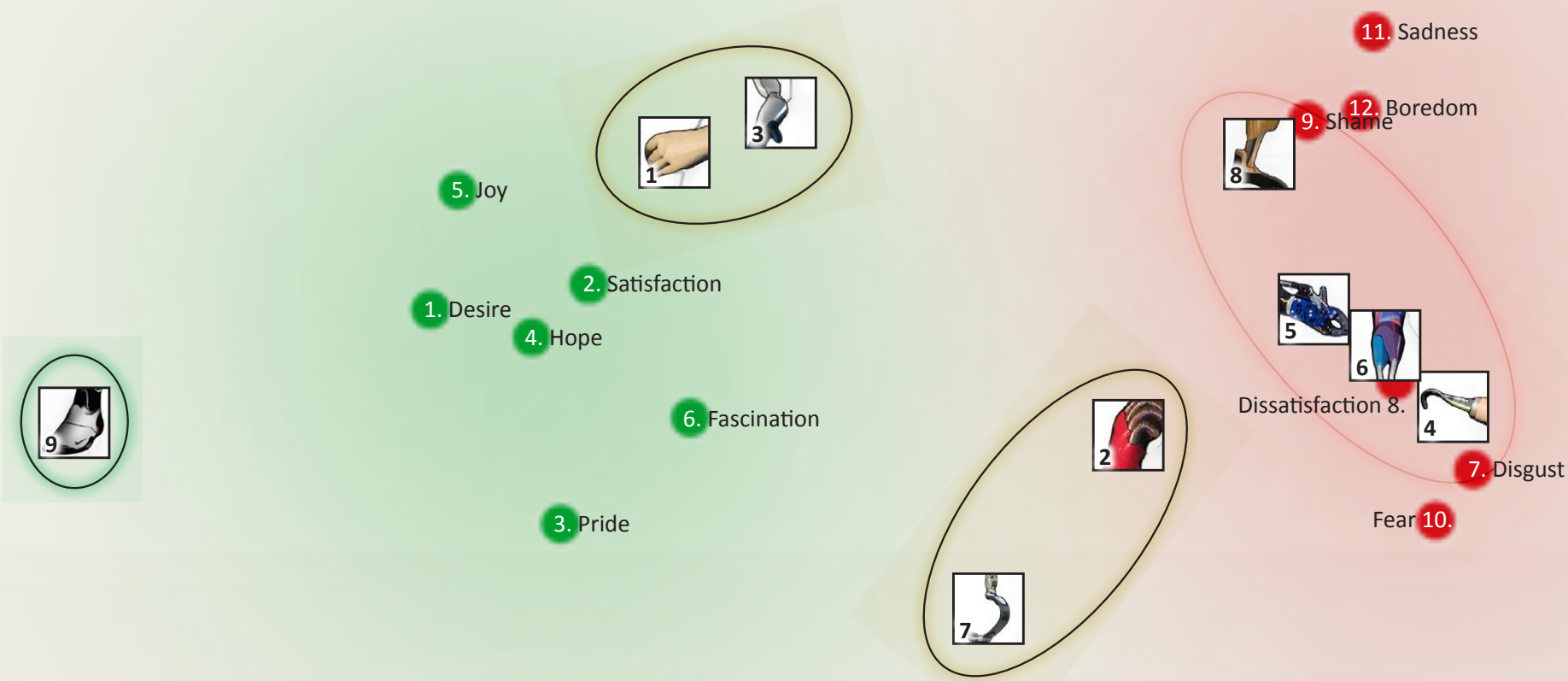


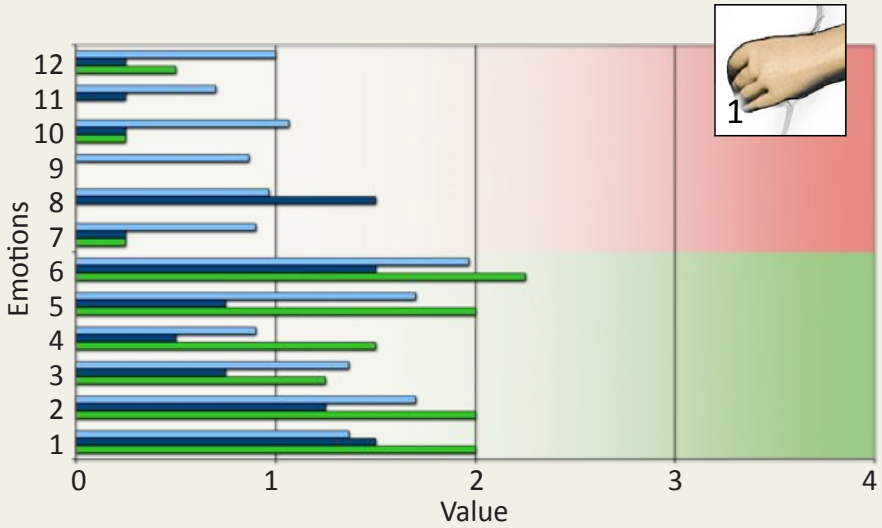
Figure 56: A 2D product space of the research results. The relative distances between the prostheses and the emotions indicate how much they are related. The distance is not an absolute measurement, but it depicts the internal proportions of the emotions.
Four main product groups can be distinguished, and they are circled in the product space.

Product space

With the PrEmo data, a correspondence analysis is performed, resulting in a two-dimensional product space of the products and emotions (figure 56 and 57). The position of the product in relation to the emotions shows the relation with these emotions. The smaller the distance, the more related they are. The distance is not an absolute measurement, but it merely depicts the internal proportions of the emotions.

The positive (green) and negative (red) emotions are typically arranged in two groups, which results in a clear horizontal distinction between positive and negative emotions. In fact, several groups of prostheses with similar emotional responses can be distinguished.

- The Nike prosthesis (9) is shown at the far left of the product space, even further to the left than the positive emotions. This indicates that this prosthesis is only related to the positive emotions.
- Next to the 'green area' is a group with the cosmetic glove (2) and the Immaculate (3). These are the two most popular hand shaped prostheses, and therefore placed close to the positive emotions. These prostheses are placed close to the positive emotions joy and satisfaction.
- Another group of two prostheses is also placed in between the 'green' and the 'red area'. These are the other hand shaped prosthesis, the Becker red hand (2) and the Össur Cheetah leg (7). These prostheses are placed close to the positive emotion fascination.
- The fourth group evokes shows the highest correlation with the negative emotions, and is therefore placed in the 'red area' on the right. This group contains all the hook-shaped prostheses (4, 5 and 6) and the Eames style leg (8).



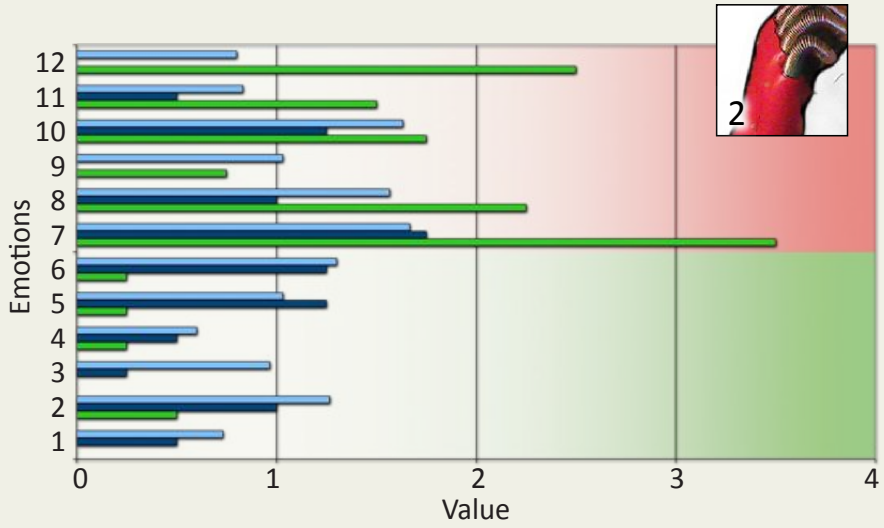
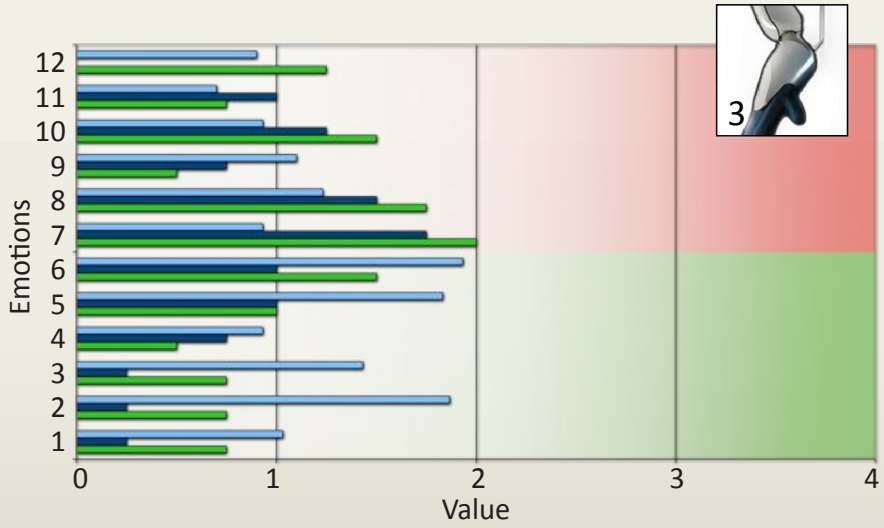


Figure 57: An overview of the mean results of the 12 emotions from the different participant groups for the three prostheses with a hand-like shape.



Legend: *Prosthesis wearers, Prosthetics professionals, Teenage peers*

Emotions:

1. Desire	*2. Satisfaction*	*3. Pride*
4. Hope	*5. Joy*	*6. Fascination*
7. Disgust	*8. Dissatisfaction*	*9. Shame*
10. Fear	*11. Sadness*	*12. Boredom*

STUDY 1: PART 1: PREMO

HAND-SHAPED PROSTHESES

Cosmetic glove with WILMER© Open Fitting (1)

- ...is perceived the most positive of all arm prostheses. All the participant groups are positive about this prosthesis, especially the prosthesis wearers. Satisfaction, fascination and joy score very high. Joy has the most diverting responses, and the professionals give a much lower rating for joy.
- ...is appreciated by the prosthesis because of the likeness with a real arm; it is inconspicuous. The prosthesis wearers all commented that they have experienced this prosthesis themselves. It is one of the most common types of prostheses.

Prosthesis wearers: "I'm getting something like this"

Teenage peer: "Nice, because it looks like a real arm"

Becker© red hand (2)

- ...is perceived with more negative than positive emotions, especially amongst the prosthesis wearers. Fear, dissatisfaction and disgust score very high. And disgust shows an interesting extreme peak for the prosthesis wearers.
- ...is not really understood for having the possibility of personalising the colour. A colour is very personal, and there were a lot of mixed comments about the colours. Some people liked it, while others did not. People liked that this prosthesis was shaped like a hand. The prosthesis wearers all had comments uttering their disgust, and they all agreed on its ugliness.

Prosthesis wearers: "Metal fingers? We don't live in a science fiction movie, do we??!!!!"

Teenage peer: "It is still a bit scary, but you could imagine a real arm still being underneath."

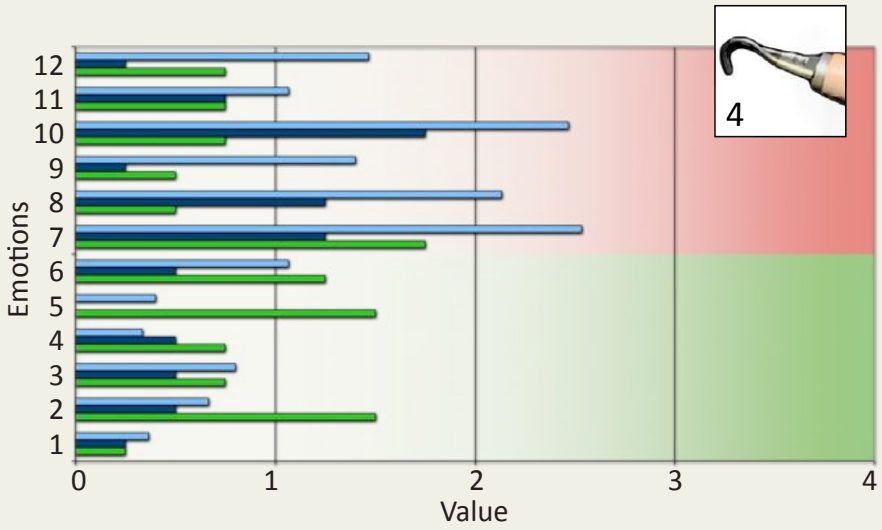
Huseklepp's Immaculate (3)

- ...was one of the prostheses with high expectations before the research, since it was designed especially for its outstanding looks. The teenage peers are slightly positive about the prosthesis, but the experts and the wearers show more negative emotions, resulting in an overview with mixed emotions.
- ...is perceived differently by participants from different participant groups. Teenage peers were positive, and commented they liked the shape. Although some did not understand the functionality and the 'mittens'.

Prosthesis wearers: "Kind of cool, I'm just curious how you could control it"

Prosthetics professionals: "Clear cut ugly. And I doubt it really works too."

Teenage peer: "I like it! It's like a female superhero arm"



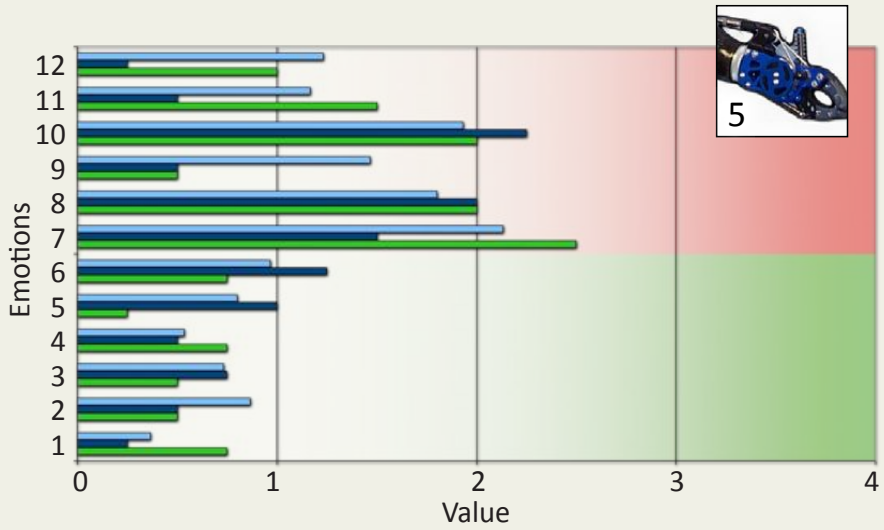
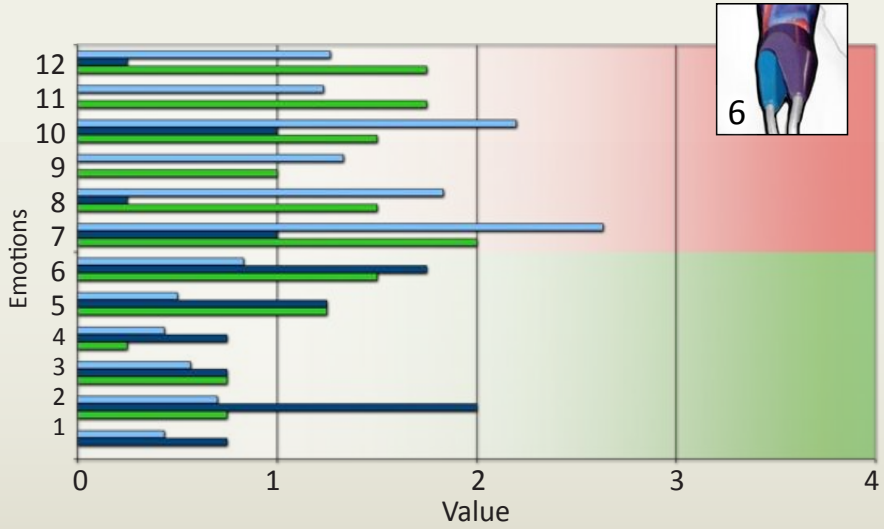


Figure 58: An overview of the mean results of the 12 emotions from the different participant groups for the three prostheses with a hook.



Legend: *Prosthesis wearers, Prosthetics professionals, Teenage peers*

Emotions:

1. Desire	*2. Satisfaction*	*3. Pride*
4. Hope	*5. Joy*	*6. Fascination*
7. Disgust	*8. Dissatisfaction*	*9. Shame*
10. Fear	*11. Sadness*	*12. Boredom*

STUDY 1: PART 1: PREMO

HOOK-SHAPED PROSTHESES

Split-hook with WILMER© Open Fitting (4)

- ...is perceived positive by the prosthesis wearers, and negative by the peers and professionals. This could be caused by the fact that they might have friends who wear such a prosthesis, and therefore have more positive associations with the product. Nevertheless they are not positive about it.
- ...gets comments about the ugliness of the prosthesis and the hook, with negative associations with pirates. Teenage peers were even frightened to get teased with such a prosthesis.

Prosthesis wearer: "I would never want one myself, but it could be functional :)"

Professional: "It is impossible for me to look at this prosthesis without considering its functionality. It looks like hell, but it is functional though!"

Teenage peer: "I think anyone with this prosthesis would really get teased with being a pirate and all."

Lesa© hook (5)

- ...is unanimously thought to be the least popular prosthesis with the most negative and the least positive emotions associated from all nine prostheses. Especially disgust, dissatisfaction and fear score very high.
- As far as could be determined in this research (see discussion), this prosthesis showed the largest difference in responses between the boys and the girls. The boys were less negative about this prosthesis, and their comments showed that they considered this prosthesis to be more 'advanced'.
- However, all participants did not like the mechanical and LEGO-like appearance of this prosthesis, and even reported negative associations with robots.

Prosthesis wearer: "For whoever has to wear this I really hope they can cover it with a glove!"

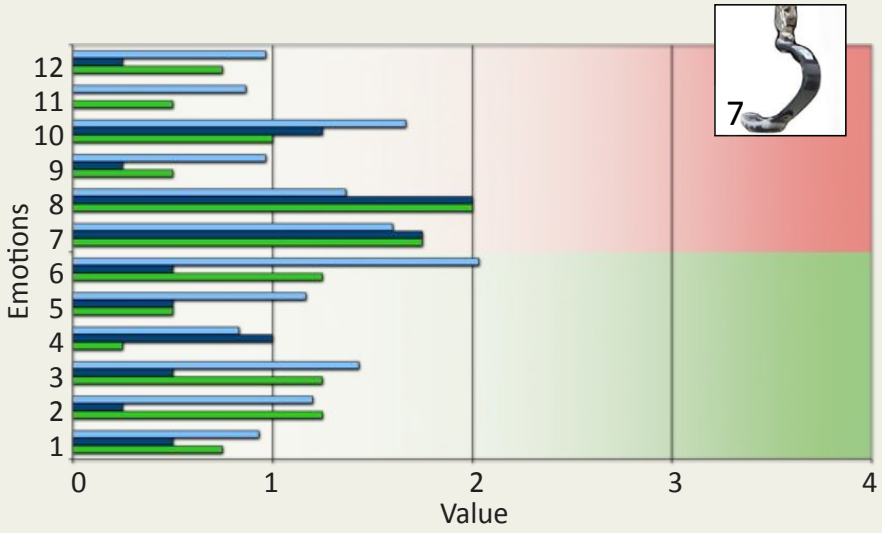
Professional: "Unfortunately, the gloomy and mechanical appearance is superior to the knowledge that it could be a strong and functional prosthesis"

WILMER© Appealing Prehensor (6)

- ...is disliked by both the wearers and the teenage peers, but professionals think positive about this prosthesis. This prosthesis is designed to be an improved version of the regular split-hook (4), but in this research it gets more negative emotions than the regular split-hook, especially when looking at the wearers.
- ...has an appearance with quite extreme colours. On top of this, the participants did not fully understand the personalizability of the prosthesis, so they judged mainly on the visible appearance, which they did not like. Teenagers thought these colours were too much and too childish. One participant responded that the colours might be useful if you could adjust them easily to fit your clothing. Professionals on the other hand already know the functionality of the hook, and base their opinion on this. They like the colours better, and appreciate the prosthesis. This prosthesis is seen as the improved version of the regular split-hook prosthesis (4).

Prosthesis wearer: "I don't like hooks, and the colours are 'slightly' exaggerated"

Professional: "The appearance could not be further away from a normal arm, but functionally it is the next best thing, and quite fashionable to see. It looks 'less like a hook' than the usual split-hook."



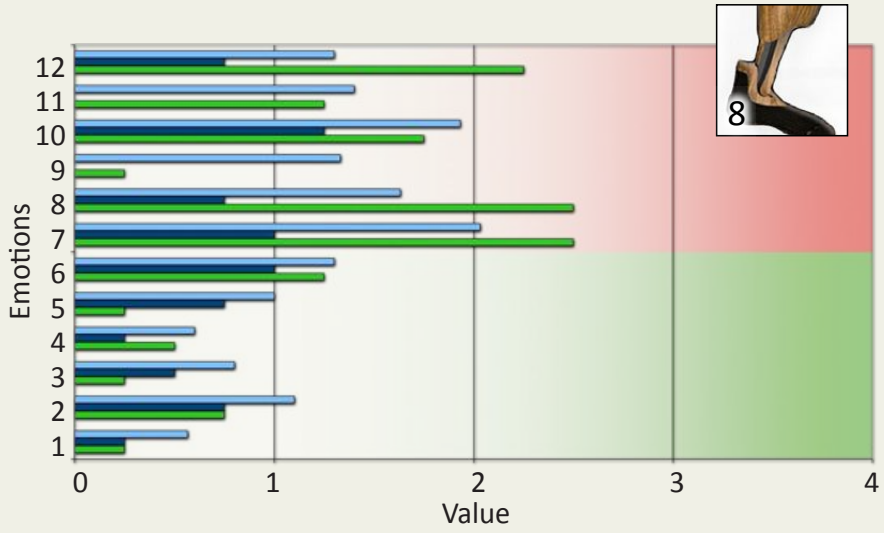
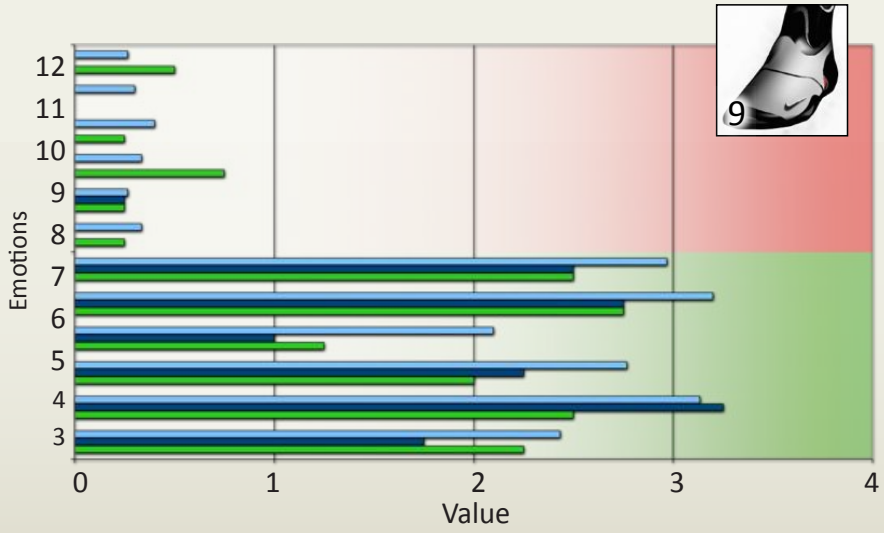


Figure 59: An overview of the mean results of the 12 emotions from the different participant groups for the three leg prostheses.



Legend: *Prosthesis wearers, Prosthetics professionals, Teenage peers*

Emotions:

1. Desire	*2. Satisfaction*	*3. Pride*
4. Hope	*5. Joy*	*6. Fascination*
7. Disgust	*8. Dissatisfaction*	*9. Shame*
10. Fear	*11. Sadness*	*12. Boredom*

STUDY 1: PART 1: PREMO

LEG PROSTHESES

Össur© Cheetah leg (7)

- ...scores mixed emotions that are predominantly negative, especially for the prosthetics professionals. High scores for disgust and dissatisfaction, but also for fascination.
- ...gets mixed responses from the participants. Half of the participants appreciate the cool and sporty side of the prosthesis, but even more people acknowledge that it looks kind of weird and funny. So amongst several negative emotions, teenage peers show a large fascination for this prosthesis.

Professional: "Not pretty, but top-functional"

Teenage peer: "It could be used with sports, but it looks quite frightening to me"

Eames style prosthesis (7)

- ...is very much disliked, with high scores for disgust, dissatisfaction and fear. However, this prosthesis gets really low scores for 'shame'. Wearers and professionals both show no association at all with this negative emotion.
- The low score for 'shame' is remarkable, since this is a wooden leg, and therefore many participants utter their associations with pirates again. On top of this, wood is also perceived to be old-fashioned and awkward.

Prosthesis wearer: "I think wood is very heavy to wear. Plus you could suffer from woodworm :)"

Professional: "Not so nice and quite clumsy"

Teenage peer: "It is a wooden leg... so you'll look just like a pirate"

Nike© sports prosthesis (9)

- ...really stands out in an extraordinary way, with very high scores for the positive emotions, and almost no associations with the negative emotions.

  Even more remarkable is the fact that all participant groups agree in their positive opinion about this prosthesis.
- ...is liked by participants from all groups. Even though it looks quite touch and masculine, girls also appreciate the sporty appearance and brand. One participant even comments that he wants such a prosthesis, even without really needing one. But in general, the 'hope' to get such a prosthesis is the least favourite positive emotion.
- Despite all the positive responses, the prosthesis wearers would not want an arm prosthesis in the same style as this leg. Apparently, what works for a leg can not be mapped to an arm, just like that. Legs and arms are different in many ways, and this also counts for the products that replace these limbs.

Prosthesis wearer: "This is a nice prosthesis. I did not even know Nike could make this. I looks like it functions well"

Professional: "Reminds me of sport, motion and speed. It looks both fashionable and natural"

Teenage peer: "This is the best! I want this even without needing a prosthesis! Wicked sick!!"

Comparison	**Split-hook**	Lesa **Hook**	WILMER **Appealing Prehensor**	Össur **Cheetah**	Eames **Wooden leg**	Nike **Sports leg**
Cosmetic Glove	**More** + Satisfaction, Pride, Desire **Less** - Disgust, Fear, Dissatisfaction	**More** + Desire, Fascination **Less** - Disgust	**More** + Satisfaction, Pride, Desire, Fascination **Less** - Disgust, Fear	*None*	*None*	**Less** + Satisfaction, Pride, Desire, Fascination, Hope, Joy
Becker **Red hand**	*None significant differences*	*None significant differences*	*None significant differences*	*None*	*None*	**Less** + Satisfaction, Pride, Desire, Fascination, Hope, Joy **More** Disgust, Fear, Dissatisfaction
Huseklepp's **Immaculate**	**More** + Satisfaction, Joy **Less** - Disgust, Fear	**More** + Satisfaction, Joy, Fascination **Less** - Disgust	**More** + Satisfaction, Joy, Fascination **Less** - Disgust, Fear	*None*	*None*	**Less** + Satisfaction, Pride, Desire, Fascination, Hope, Joy

Figure 60: This tables gives an overview of all the different emotions that showed significant differences in a pairwise product comparison. Only the most interesting part of the full matrix is shown; the comparison between the hand shaped prostheses and on the other side the hook-shaped and leg prostheses. Any significant differences are indicated by red and green area's, indicating that the hand-shaped prostheses were significantly better or worse.

STUDY 1: PART 1: PREMO

SIGNIFICANCE

All the values for the separate emotions are compared pairwise by product, with a Multi-Analysis of Variables (MANOVA), to see if the observed differences are significant or just coincidental. This analysis is only done for the 30 participants in the teenage peers group, since the other groups are too small.

Between products

The most significant differences are found with the Nike sports leg (figure 60). This prosthesis is valued significantly better for almost every positive emotion and some negative emotions in comparison with any of the other prostheses. Especially the positive emotions show significant differences compared to the other prostheses. The Nike sports leg shows significantly more positive emotions than the hand-shaped prostheses.

Other significant differences exist between the hand-shaped and hook-shaped prostheses, where the cosmetic glove and the Immaculate are valued significantly better than any of the hooks.

The Immaculate and the cosmetic glove both shows significantly more satisfaction and fascination and also less disgust and fear. The most striking dissimilarities occur for Joy and Pride. The Immaculate evokes significantly more joy than the hooks, while the cosmetic glove evokes more pride.

This might be caused by the fact that the prosthesis wearers feel more proud of their body when they feel 'complete'; with an inconspicuous and natural looking cosmetic glove.

The Immaculate appears more joyful, and this could be caused by the promising prospect of the several ball and socket joints that allow for great movability. On top of that, the Immaculate has an enjoyable modern design.

Between groups

Three different participant groups with a different interest in prosthetics were used. Not just to increase the number of participants, but also to evaluate how prosthesis wearers relate to their peers and their professionals.

Despite the low number of participants, a univariate test was performed to analyse whether belonging to a certain group has an effect on the emotional responses. As predicted, no true significances (P=0.95) could be found. However, for two products the differences approached significance (P=0.90). These two products were the split-hook with WILMER Open Fitting and the Nike Sports leg.

When we look closer to these differences between the groups for each prosthesis and each emotion, the first observation is that there are just very little significant differences found. As indicated before, this unfortunate outcome could be the result of too little participants in some of the groups.

- No significant or near significant differences between groups were found for the emotional responses in prosthesis 1, 3, 5, 6, 7 and 9.
- The wearers show significantly more boredom for the Becker red hand than the professionals do.
- The wearers show significantly more joy for the skin coloured split-hook than the professionals and the peers.
- The wearers also show less fear for the skin coloured split-hook than the peers.
- The wearers show more dissatisfaction for Eames wooden leg than the professionals.

It might seem like a little, but even these few significant differences support several earlier assumptions.

Figure 61: If this research would be about winning, this prosthesis would definitely be the champion. This fictitious leg was unanimously appreciated by all participant groups.

STUDY 1: PART 1: PREMO

CONCLUSIONS

The primary goals of this first research part was to answer a main research question. In the previous analysis, special attention is paid to this objective, with observations, findings and assumptions.

This paragraph will now summarize and conclude these findings to answer for the following research question.

What emotional responses do the prosthesis wearers, their peers and their therapists have towards the presently available prostheses designs, and how does this relate to the prosthesis humanity?

Hand-shape

Participants appreciate prostheses that have a natural shape, like it is actually covering a limb. The cosmetic glove gets very positive emotional responses, and of course there is the super popular Nike sports leg (figure 61). Comments about this Nike prosthesis show that people appreciate the fact that the prosthesis resembles existing footwear and sports shoes, like it is worn on a healthy leg.

Colour is personal, so it should be used with caution. If there is a fixed colour, some people will like it, but the majority will prefer a different colour. If there is a personalisable colour, people will still judge only the presented colours.

Despite all the assumptions in the first chapter about skin coloured prostheses, participants do appreciate the skin colour of a prosthesis, at least on first sight. This unexpected popularity could also be caused by the fact that only the prosthesis is shown in the research pictures. In a comparison with a real arm, the mismatch with the actual skin colour will be evident, and the prosthesis could be perceived less positive.

Functionality should be clear in order to get appreciation. If the functionality in unusual or unclear, like with the Immaculate (6) and the fingers of the Becker red hand (2) this is bad for the appreciation of the prosthesis. In other words, a prosthesis that looks like it is well functioning is appreciated.

Hook-shape

Despite their functionality, hooks in general are very strongly perceived as being frightful and disgusting, by all groups, but mostly by the teenage peers. Associations with pirates and robots are strong, and will also make a wearer an easy target for teasing.

The skin colour of a split-hook prosthesis seems obsolete, since its function is completely undone by the unnatural hook shape. The uncanny valley can also be used to explain this wrongful mixture of human and artificial characteristics. It is therefore no surprise that this prosthesis gets negative emotional responses. Nevertheless, the wearers are significantly more positive towards this prosthesis. A reason for this might have friends who wear such a prosthesis.

The WILMER Appealing Prehensor is perceived very positive by the professionals, probably because they know it's value, and they might be a little prejudiced by this. The prosthesis wearers and teenage peers on the other hand judged very negative about this prosthesis, possible because they did not understand how this prosthesis can be personalised, and merely judged it on the presented colour palette. However, not all people that did understand the personalizability, did also appreciate it, so perhaps there is more to it.

Legs

Wood in combination with a leg evokes stigmatising negative associations with pirates. These types of 'design errors' are easily avoided, or associations might even be used as an advantage.

The Össur Cheetah leg is trying to use association in their advantage, the association with the speed and power of cheetahs. This works, but not all the time, and not for everyone. Some people do not get the similarity with a cheetah, and others think it looks more like other animals or mechanical devices.

The Nike sports leg and the Össur Cheetah leg both get positive responses for their 'superhuman functionality'. But the difference with the Nike leg is that the Össur leg is still perceived negative because of its frightening appearance. This leads to the conclusion that good functionality is not the only issue for prosthetics. It might work for a specific sports prosthesis in a specific context, but this does not make it suitable for daily life.

Despite all the positive responses, the prosthesis wearers would not want an arm prosthesis in the same style as this leg. Apparently, what works for a leg can not be mapped to an arm - just like that. Legs and arms are different in many ways, and this also counts for the products that replace these limbs.

Figure 62: Arms and legs are different in many ways, and this also counts for the products that replace these limbs. A successful leg does not necessarily guarantee a successful arm in the same style.

STUDY 1: ANALYSIS

PART 2: INTERVIEWS

Research question

Which prostheses designs are perceived most and least popular by the prosthesis wearers, and how does this result from their emotional responses and underlying concerns?

Approach

The emotional data gathered in part 1 is detailed further in part 2. The participants are asked to sort the same products on personal preference, and explain and found their choices in respect to their PrEmo results. The ultimate goal of the interviews is to find the underlying concerns of the participants, and their likes and dislikes towards the presented designs.

The participants in part 1 are asked for their willingness to also participate in part 2. Of them, 5 random participants are invited to do these interviews. The random selection is only based on the interest groups. Teenage prosthesis wearers are preferred, but on deficit they can be complemented with therapists.

Results

The obtained data will be structured according to the three levels of product attachment, as they are described on the first pages of this chapter: product-focussed, activity-focussed and self-focussed.

These prosthesis wearers will be introduced in the next few pages by means of a persona (figures 63-65). The persona's give a complete image of who the participants are, by means of a short description of their prosthesis history, a picture and some personal details. To still protect their anonymity, the image is slightly censured, and they are called by a fictitious name.

The results of the study will give a direct overview of the likes and dislikes of the participants, as well as their concerns and motives in the three levels of product attachment. This information can be linked to the results of the PrEmo research. More conclusions can be drawn from the differences between the interest groups and the prostheses categories.

PERSONA - PAULA

Figure 63: This is Paula, with her 13 years, she is the only teenager in the interviews. She is born with a defect of her left arm, and has learned to live normally without it. When she was 7, her parents choose a myo-electric cosmetic prosthesis for her to wear. This prosthesis was not such a big success; it was warm, annoying and clumsy, so she rather did not wear it. Recently, she has changed her mind about prostheses, and she choose to start wearing a myo-electric cosmetic hand again, this time with Open Fitting. She is expecting to get her new prosthesis soon.

Paula: "The children in my class wanted to experience how it is to have only one hand for once. So they tied one hand in gym class, and then we did dodgeball... Everyone acted really funny with catching and all. And of course I had the advantage: I already practiced this all my life!"

STUDY 1: ANALYSIS

PART 2: RESULTS

Also see appendix C, M

Concerns

The interviews continued about what the interviewees thought about the nine prostheses, and this is already covered quite well by the first part of the research. The real added-value of the interviews lies in the (subconscious) concerns behind their thoughts. Their motivations to make decisions regarding prosthetics.

These concerns can be divided into three main categories, regarding the interest.

- **Self-focus**: Owning and using a product also has its influence on the identity of the user. Products can affect how the user is perceived by others, but also have their affect on the self-image. Appraisals come into being because people are emotional about who they are and how others perceive them.
- **Product-focus**: A product can have a very direct emotional impact as such. The results of seeing, touching, tasting, hearing and feeling might elicit emotions, and can all be directly attributed to the product characteristics. This context of experience includes not only the actual perception of a product, but also the our goals and expectations.
- **Activity-focus**: Products are used to enable and facilitate all kinds of activities. These activities themselves can be useful, pleasurable or rightful. In this case, the emotion is focussed on the action, and not the product.

The concerns that can be extracted from the interviews will be listed in these three categories, and can be used to formulate

Self-focus

- During the interviews, the most important requirement for a prosthesis undoubtedly appeared to be looking like 'what you should normally have': a real arm. In shape, but also in colour and motion. The interviewees indicated that they do not feel disabled at all, but they might be stigmatized in this way 'by others', especially in public places when they are surrounded by unknown people. They want to blend in and look normal, and therefore look for an inconspicuous prosthesis. In a way, they are definitely affected by the interpretation of their social environment, especially during puberty.
- This means that prostheses with a natural shape are preferred over those with an artificial shape. Skin colour is preferred over bright colours and patterns. Natural appearing plastics are preferred over distinct metals and wood. A movable hand is preferred over a passive hand. And a natural position of the hand is preferred over a hand in gripping position. This also explains why myo-electric prostheses are preferred over body powered prostheses: for the simple fact that you don't have to make any less natural odd movements to perform the grabbing.
- The Open Fitting might be easier, but it is also less natural. This makes the wearers want to cover the Open Fitting, even though this means occasional discomfort. The brace is broader than the arm: it protrudes. Resulting in visibility through (tight) clothes, and it may also hinder while dressing.
- People want their prosthesis to be unique, so personalising it with a colourful and conspicuous print is appreciated, as long as it can be covered when necessary. They want to have an inconspicuous arm whenever they want. This 'switching' is not supported by any of the current prostheses, because cosmetic gloves can not easily be put on and of, and additional (winter) gloves are very difficult to wear over a cosmetic glove.

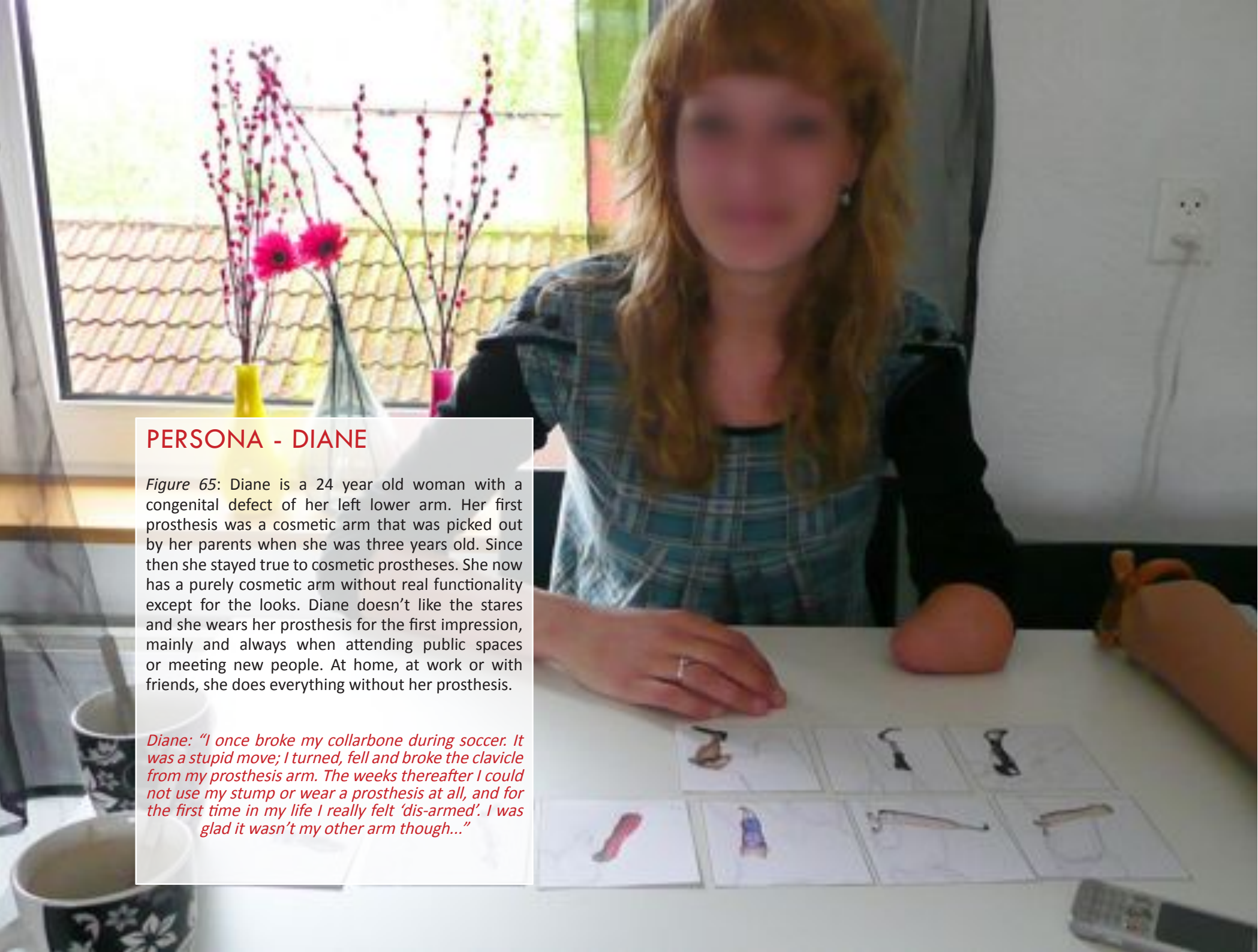
PERSONA - ROY

***Figure 64*: Roy is a 21 year old student, who was born without his right arm. His parents got his first prosthesis when he was two years old, and they immediately focussed on myo-electric, resulting in a prosthesis with added weight. During lower school, he had to use his prosthesis a lot for fine motorial activities, and became very skilled. Skills which he neglected when he started using a computer without prosthesis. He now switches between a cosmetic arm and a myo-electric cosmetic arm, and wears his prosthesis mainly for the first impression on special occasions.**

- There is also a huge difference between congenital and traumatic defects, since the people with an acquired defect already experienced how it is to have two hands. They will actually miss their arm, while people with a congenital defect will not even consider themselves to be slightly less-abled. The number of people with acquired defects increases with age, so the vast majority of teenagers with a prosthesis will have a congenital defect.
- Whatever the exact reason is to wear a prosthesis, it really has to be the wearers choice. The wearer has to see the benefits of the prosthesis himself, and also experience those in daily life, otherwise it is very easy to put the prosthesis aside again. But when the prosthesis is accepted, they are unlikely to switch to something else. They are loyal consumers.
- Some wearers do not wear their prosthesis all the time, but there is also a threshold to not wear a prosthesis in a new environment. This again involves the insecurity about what unknown 'others' might think and say, for instance at work or at school. After a while, when everyone knows about the prosthesis, the threshold is much lower. Empathic feelings of others about fear and shame are also considered. Remarkably, holidays are an exception to this rule.

Activity-focus

- The activities that can be performed with a prosthesis are dependent on the type of prosthesis. Passive prosthesis have a supporting function, and can be used to make a hand-stand in gymnastics or to lean on the steer of a bicycle. These types of activities are generally pushing forces. However, activities that require pulling forces can not be performed, like hanging on the rings in gymnastics or carrying a heavy shopping bag.
- Swimming is also possible with a passive prosthesis, with a few side notes. Some prostheses contain wood, which is naturally not very compatible for water. And the prosthesis always contains a hollow socket, which will fill up with water. Leaving no other option than to remove the heavy prosthesis to empty it.
- Powered prosthetics are more fragile because of the mechanical and moving parts, and therefore have to be used more cautious. These prostheses are more suitable for smaller pushing forces and - due to their gripping ability - pulling forces. These prostheses are also more vulnerable for water and dirt, especially when the prosthesis is electrical powered. Small exposures are endured by the glove, but swimming or playing in sand is often not possible.
- An average cosmetic glove must be replaced every two months, and this is difficult maintenance action for which the wearers are unfortunately dependent on the prosthesis makers. But in the mean time, these plastic gloves are exposed to many damaging situations. Even the rubbing of clothes will damage the glove, and wipe out the fine details - that are highly appreciated by the wearers. This causes the wearers to always be careful and cautious with everything they do.
- Specific activities can also make the glove very dirty, but cleaning thereof is often difficult or even impossible, dependent on the material of the glove and the stain. Wearers will always have to be observant for the surfaces they touch with their prosthesis, like writing or reading a newspaper due to the ink. Not to mention real dirtying activities like household chores, outdoor sports, gardening and garage work.
- Also specific hobbies and occupations will have a different effect on wearing a prosthesis. A car mechanic will have other requirements than an office clerk. In other words, prostheses are very personal products. And the situations in which a similar prosthesis can be used are extremely diverse.
- Some activities can even be performed better without a prosthesis. Activities that require fine



PERSONA - DIANE

Figure 65: Diane is a 24 year old woman with a congenital defect of her left lower arm. Her first prosthesis was a cosmetic arm that was picked out by her parents when she was three years old. Since then she stayed true to cosmetic prostheses. She now has a purely cosmetic arm without real functionality except for the looks. Diane doesn't like the stares and she wears her prosthesis for the first impression, mainly and always when attending public spaces or meeting new people. At home, at work or with friends, she does everything without her prosthesis.

Diane: "I once broke my collarbone during soccer. It was a stupid move; I turned, fell and broke the clavicle from my prosthesis arm. The weeks thereafter I could not use my stump or wear a prosthesis at all, and for the first time in my life I really felt 'dis-armed'. I was glad it wasn't my other arm though..."

motorial skills, like typing on a computer or using needle and thread. All in all, this is also a matter of training and acquiring skills.

- Financing a prosthesis is often controlled by the health insurance companies, at least in The Netherlands. They have their own requirements, which the wearers have to meet in order to avoid major personal expenses. This also causes the teenage wearers to only have one prosthesis for everything, even though they might require a more specific functionality for different situations.
- Wearing a prosthesis is encouraged by therapists, because it will lead to a more natural and symmetrical body posture. Which again will lead to fewer complaints for shoulder and back pain, and less additional physiotherapy.

Product-focus

- The Open Fitting makes the prosthesis easy and quick to put on. Something that is important a person does not like to wear their prosthesis all the time. People with a congenital defect are often very skilled with their stump, and only wear the prosthesis for the appearance.
- A normal closed fitting requires a sock to be able to put the prosthesis on. This is a timely procedure, especially with young children.
- Wearing comfort is also an important concern. A prosthesis with a closed fitting is warm and sweaty to wear, especially in the summer. Therefore the Open Fitting is preferred over a regular fitting.
- Functionality has to be evident. If the functioning of a prosthesis is not clear, a wearer will not like it, not buy it, and therefore never try it. Just like with any other type of products, looks can be decisive (and deceiving).
- Myo-electric prosthetics are powered by batteries that are located in the socket. Two batteries are supplied with the prosthesis, and they have to be replaced to be charged. The battery is covered with the cosmetic glove, which makes it difficult to remove. Positioning these large batteries becomes easier when the wearer and thus the prosthesis become bigger. But charging remains an inconvenience.

Figure 66: A schematic representation of the results from the interviews, displayed in mindmap kind of way.

STUDY 1: PART 2: INTERVIEWS

CONCLUSIONS

The concerns that resulted from study 1 already touched upon the conclusions of this chapter. These concerns are the motivations of the prosthesis wearers to wear their prosthesis, and reveal precisely what is important to them.

Please note that all the interviewees wear a cosmetic prosthesis, with or without a functional hand. This means they all share a similar desire for humanity, and this naturally shows in their concerns.

CONCERN PROFILE

In short, the most important reason to wear a prosthesis is to appear normal and natural. Therefore a prosthesis needs to possess several characteristics that can be altered or used to obtain this humanly appearance: position, posture, shape, colour, material, function and motion.

However, in contradiction to the humanly appearance, the interviewees indicated that they would like their prosthesis to be personal and unique. And maybe this is not even so different from a humanly appearance: every body part is unique, starting as small as a fingerprint. 'Normal people' can extend their uniqueness with decorations like tattoos and jewellery. Prosthetics could be altered even more radically, while instead they now feel more like impersonal mass products. A prosthesis could be treated more like a fashionable accessory instead of a functional limb replacement. Similar to jewellery, prosthesis wearers want the possibility to make their prosthesis inconspicuous again when necessary.

Prosthesis wearers generally do not have trouble with activities due to the loss of their arm, especially when they were born with this defect. They learn to live with one arm, and adapt perfectly. In fact they don't need the expensive features of a bionic hand at all. They are comfortable with their appearance, but they feel societies pressure to look normal, a feeling that is exaggerated during puberty.

The most important context to wear a prosthesis is in public places, and other events where one might encounter 'strangers', with the only reason of appearing normal at a first impression. Many sports, hobbies and occupations could be performed without a prosthesis, but also take place in a public environment.

Prosthesis wearer: "I once broke the collarbone of my prosthesis arm during soccer. The weeks thereafter I could not use my stump or wear a prosthesis at all, and for the first time in my life I really felt 'dis-armed'."

Furthermore, there are also some practical issues about their prostheses, like choosing and obtaining a prosthesis, having a comfortable fitting, and maintenance activities like cleaning, changing batteries (for Myo-elektric prostheses) and periodic check ups. Especially their vulnerable cosmetic glove makes them dependent on the orthopaedic instrument maker.

All these concerns and other findings will be used in the next chapter, to build a 'product profile' and create ideas for product improvements.

Figure 67: Advertisement for the TV series Nip/Tuck shows a bad example of the use of laces. To avoid responses of repulsion, laces must never be used on a skin-coloured material. This mixture of humanity and artificialness can also be explained by the uncanny valley theory.

CHAPTER 3: DESIGNING COOL ARM PROSTHETICS

THIS CHAPTER

This third chapter starts where last chapter ended, the concern profile. The concern profile is translated into a product profile with a design vision and problem definition to provide guidance in the idea generation. The product profile will be based on the research data and all other information collected throughout the project.

In this chapter, the actual designing begins. Ideas were formed throughout the entire project already; by doing literature research, conversations with experts, comparative research with teenagers and interviews with prosthesis wearers. This chapter describes the process of idea generation and the accompanying creative tools that are part of the conceptualization phase.

Eventually, all the sketches and ideas result into three concepts suitable for further research.

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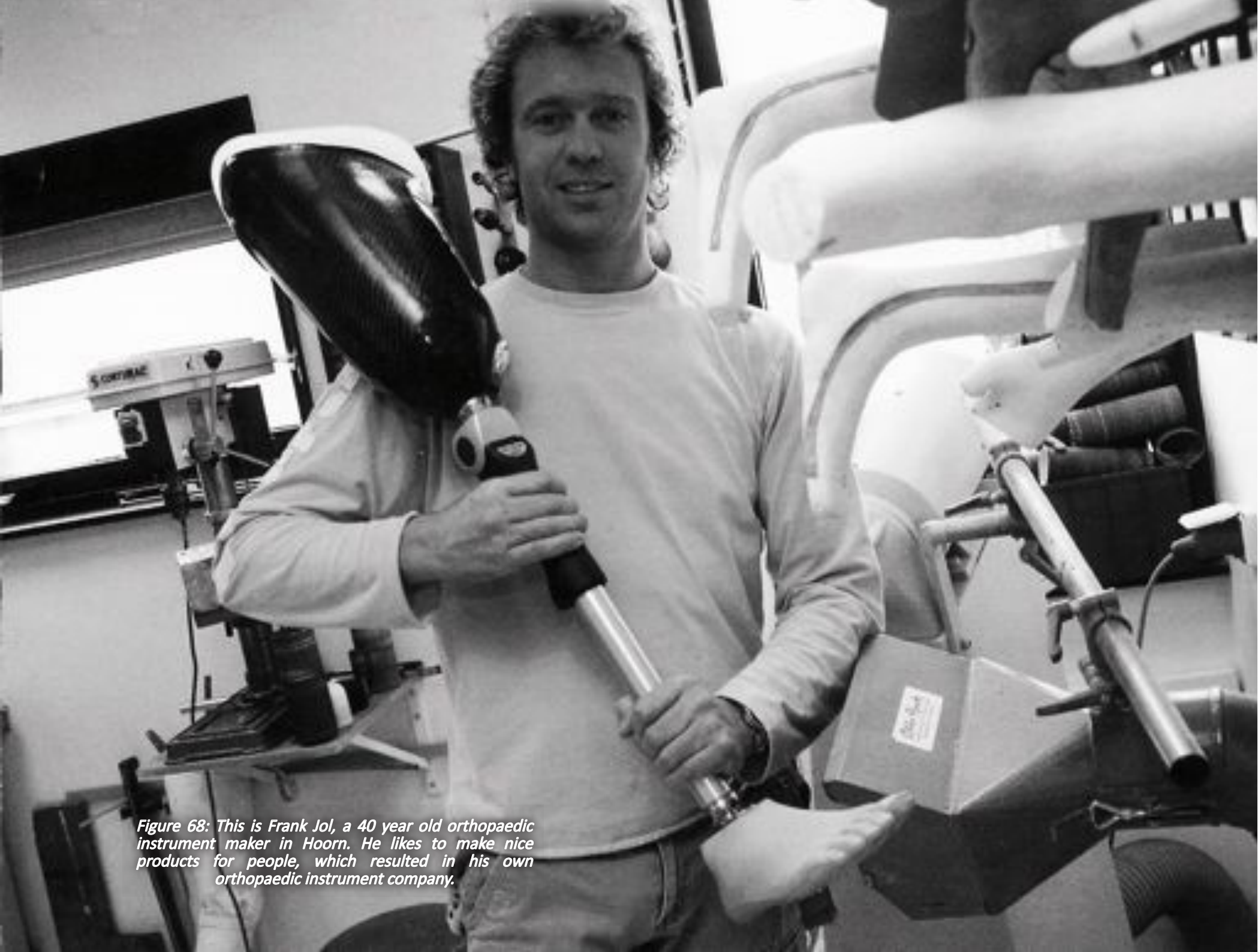


Figure 68: This is Frank Jol, a 40 year old orthopaedic instrument maker in Hoorn. He likes to make nice products for people, which resulted in his own orthopaedic instrument company.

EXPERT INTERVIEW

Frank Jol, Orthopaedic instrument maker

Also see appendix N

In this conceptualizing chapter, several assumptions and conclusions from the first research chapter have been used. The purpose of this interview is to get the opinion of an independent expert regarding these conclusions and assumptions serving as a reliable basis for the ideas created throughout this chapter.

This interview is held with orthopaedic instrument maker Frank Jol (figure 68), one of the major prosthesis makers in The Netherlands. His company has annexes in Hoorn, Alkmaar and Rotterdam. The interview transcript can be found in the appendices .

Frank Jol has founded the company of the same name about 12 years ago, and the company has grown and now employs 16 people. Leg prosthetics have always been their main business, simply because the market is much bigger. Nonetheless, Frank Jol also does arm prosthetics, orthotics and he also specialises in tailor-made sports prosthetics. For this reason, he is a major supplier for Paralympic top athletes, as well as the average man in the street.

Getting a prosthesis

Judged by the numbers, prosthetics is a real niche market, and thus a field in which it is difficult to set up a successful production line for new products. You have to be innovative with the available means: use the existing modular adaptors to create unique prostheses.

Frank Jol thinks it is important to let people perform at a level as high as possible, specifically when they are amputees. Good physical abilities introduces a vicious circle that also leads to a better self-esteem, and it makes any handicap less of a handicap.

The problem with amputees is that they grow up hearing only what they are not able or allowed to do, because of - what others consider - a handicap. Frank Jol tries to give them a more realistic image of their capabilities. He provides the means, but in the end it is still all up to the prosthesis wearers themselves. Providing information is half of the work I do here.

Frank Jol: "Sometimes a person walks in with all kinds of desires and expectations, like this is Lourdes or something. 'Frank Jol can make anything, so he will solve my problems for me.' And of course its up to talk them into more realistic expectations."

Niche market

Conform earlier findings, Frank Jol mentions that the market for arm prosthetics is extremely small, and also much smaller than for leg prosthetics. In addition to this, practically everyone with a leg amputation uses a leg prosthesis, but for arm prosthetics this percentage is much lower. Not every arm amputee owns an arm prosthesis, and not all owners use their prosthesis daily.

Frank Jol acknowledges that leg prosthetics are easier to make than arm prosthetics. His experience shows that the more distal an amputation is, the easier a prosthesis will be accepted. An arm prosthesis is less distal than a leg prosthesis, and therefore less likely accepted. And also a lower arm prosthesis is more likely to be accepted than an upper arm prosthesis. Although this will also have to do with (lack of) functionality.

Frank Jol: "Look, you can not walk without your leg. But you can still function very well with only one arm."

Children

Parents often decide to get an arm prosthesis for their amputee children. Starting as soon as a crawl-prosthesis for babies.

The children wear their prosthesis faithfully until they become teenagers, become pubescent. They get more emancipated and start deciding things for themselves, instead of letting their parents decide for them. The

Figure 69: Sunglasses look great outside, but rather stupid inside. Unless of course, when you are a celebrity constantly blinded by flashing lights...

teenagers discover how they can function perfectly without a prosthesis.

Frank Jol: "I see it often: when children reach puberty, they feel that wearing and using a prosthesis is worse than just missing an arm"

In the age of 14 to 16, when they might get their first boyfriend or girlfriend, they want their prosthesis again. Especially for a good first impression: appearance becomes more important.

They might wear the prosthesis again for several years until their twenties. But eventually they stop wearing the prosthesis for activities of daily life (ADL), and start looking for a prosthesis with more specialised functionality. Appearance becomes less important. They might need their prosthesis to perform in their job, hobby or sport.

Sports prostheses

Frank Jol also makes sports prostheses for amputee athletes. Both amateurs and professionals. This market is much smaller than the normal prosthesis market, but since he is one of the very few specialists in the country, people come to him anyway.

A sports prosthesis is always a very unique and personal piece of equipment that has to be tailor made to the wearer, the stump and the sport. This requires a unique design for every prosthesis.

Before the age of 16, children are compensated by the insurance companies for almost everything, and they can easily get a specialised sports prosthesis. But from the age of 16, the insurance companies also very difficult in supplying specialised sports and work prosthetics. Only one prosthesis for ADL is compensated. If you only stay within these borders set by the market and insurance companies, your options are seriously limited.

Improvements

Teenagers can be very insecure about how they look, and having one arm is a very conspicuous characteristic. Current prosthetics contribute to this image with their ugly skin colours and unnatural hook shapes.

Frank Jol thinks a prosthesis needs to have certain natural characteristics like shape, but colour can be used to vary. People want to appear humanly, but at the same time be different than others.

Frank Jol: "The shape and silhouette should be natural, but the colour can be conspicuous, just to avoid the shock for other people"

Another huge disadvantage is the fact that you can only get one prosthesis for ADL compensated by the insurance company, while in fact you might need 3 or 4 different prosthetics for different situations. Some leg prosthetics he designs can adapt to the situation. The legs can be used for casual and sporty situations without cover, but in formal occasions the leg can be covered with a skin-like material and a natural shape. Women can additionally wear a pantyhose to make both legs look equal.

Frank Jol: "A chameleon-prosthesis that adapts to the outfit you're wearing, that would be useful..."

Whether a prosthesis appears nice is also very much dependent on the context and the activity. Sunglasses can look very nice, but when you wear them inside a building (out of context), it looks stupid rather than cool (figure 69). That is precisely why one single prosthesis can never be suitable for every activity.

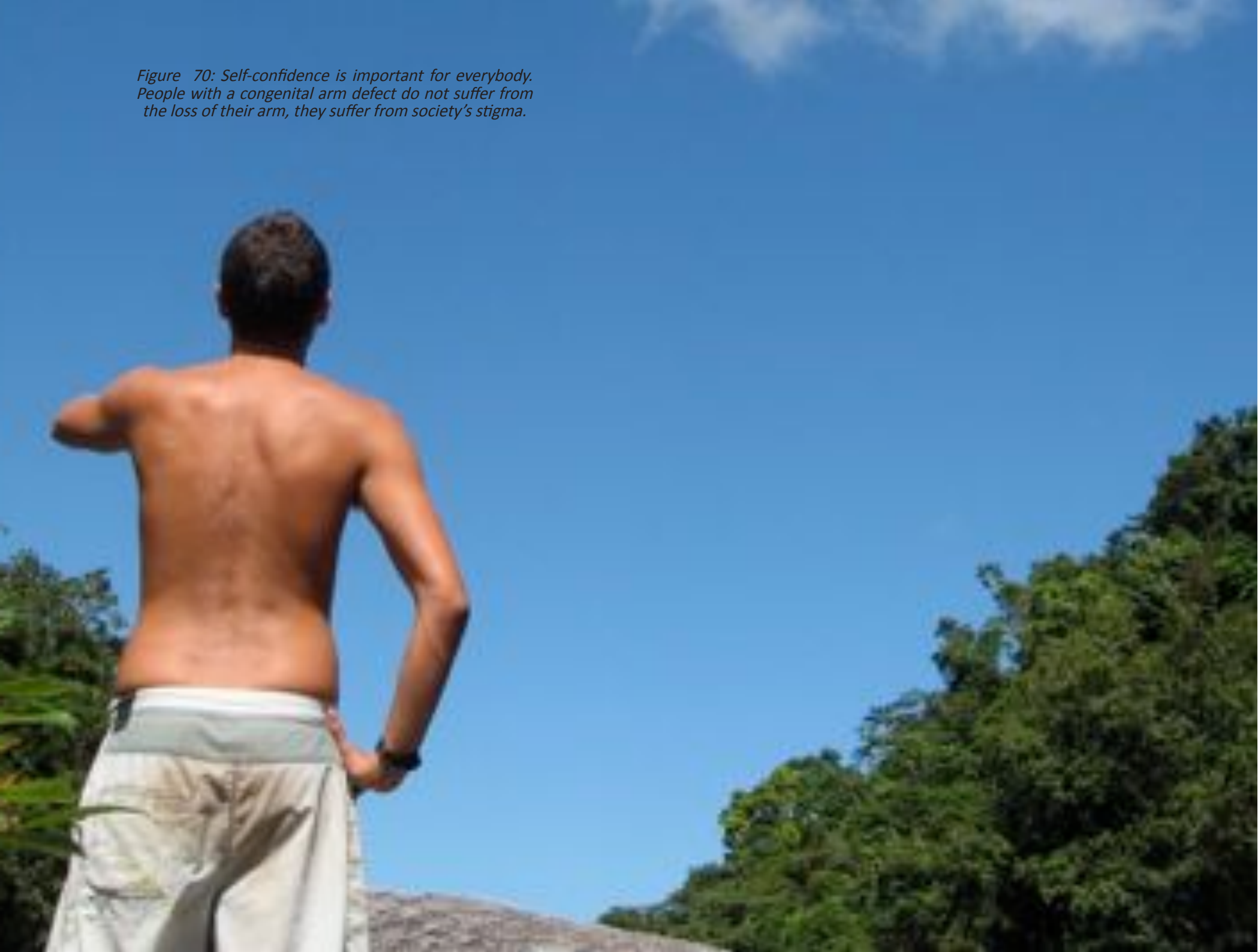


Figure 70: Self-confidence is important for everybody. People with a congenital arm defect do not suffer from the loss of their arm, they suffer from society's stigma.

PRODUCT PROFILE

The product to be designed is an arm prosthesis for teenagers with a transradial (below elbow) defect. This can be either on the left or the right arm, and it is desired that the same design can also be applied to prostheses for higher amputation levels.

The global number of arm prosthesis wearers is about 0,1% at the most, and teenagers are only a part of this. This has resulted in a niche market for arm prosthetics, with limited resources small production numbers and only little innovation. Current arm prosthetics can be divided into several main groups, but within these groups there are many variations of similar prostheses. The new product must be producible in small numbers, and without large investments for the producing companies or the wearers.

Humanly

The most important reason to wear a prosthesis is to appear normal and natural. Currently, a prosthesis is made to possess several characteristics that mimic a humanly appearance: position, posture, shape, colour, material, function and motion. Several of these characteristics can also be used to associate with a humanly appearance, without creating an uncanny copy of a real arm. After all, appearance and function should be equally humanly in order to avoid the uncanny valley.

Activities

Prosthesis wearers are concerned about the appearance of their prosthesis, and at the same time they desire functionality. This discrepancy in concerns results in a changing balance of appearance and functionality in different situations. Some situations require a more natural look with less functionality, while other situations require more functionality and not so much a natural appearance. Currently, prosthesis wearers only have one prosthesis for everything - every activity in all situations - mainly due to regulations set by the health insurance companies.

Personalisation

Next to this functional change in appearance, there are also several personal reasons to allow Personalisation: the desire to be unique, personal taste, fashion, culture and lifestyle. In fact, every healthy arm is already unique, starting already as small as the unique fingerprints.

It would be very desirable if a prosthesis could be adapted swiftly in functionality and appearance to specify to a different context and activity.

Self-confidence

Prosthesis wearers generally do not have functional disadvantages due to the loss of their arm, especially when they were born with their defect. They learn to live with one arm, and adapt perfectly (figure 70). They are comfortable with their appearance, however they feel societies pressure to look normal, a feeling that is exaggerated during puberty. Whether this feeling is appropriate is subordinate to the insecurity it origins from.

Context

The most important context to wear a prosthesis is in public places, and other events where one might encounter 'strangers'. Three main situations to wear a prosthesis can be described as *casual*, *sporty* and *chic*.

Even though prosthesis wearers learn to adapt to their situation very well, for some sports, hobbies and occupations a prosthesis can be advantageous.

Like everyone else, they choose these activities according to their capabilities and ambitions. They only have their arm defect as an additional circumstance to take into account. Increasing their capabilities and self-confidence will therefore also increase their options.

Design a product usable on current and future arm prosthetics to give teenager prosthesis wearers the opportunity to be confident and proud to wear their prosthesis.

Figure 71: Teenage insecurity, illustrating the vision.

PRODUCT PROFILE

PROBLEM DEFINITION

Teenagers can be very insecure about how they look (figure 71), and having one arm is a very conspicuous characteristic. Even though they are very well adapted to their situation, others might react surprised or even scared. Wearing a cosmetic prosthesis lowers their feeling of insecurity, even though there are several drawbacks to their prostheses.

Prosthesis wearers only get one prosthesis - for every activity in all situations - while in fact there are situations that require different prostheses with entirely different characteristics. *Sports*, *casual* and *chic* are three important contexts in which people desire a different functionality and appearance from their prosthesis.

Prosthesis wearers too want to belong to a group, but not stand out in the crowd. They want to be unique in the way they like, and not simply because of their amputation. They see their prosthesis not as a replacement of the arm, but as an accessory to the body. A means to express themselves.

Cosmetic gloves are vulnerable, maintenance sensitive and expensive. This makes the cosmetic gloves unsuitable for physical activities that people might want to perform during their occupation, sports, hobbies and daily chores. A new product should make the prosthesis wearers feel proud to wear their prosthesis, and confident enough to act with it.

Figure 72: Results from a brainstorm about Pride & Confidence.

IDEA GENERATION

Also see appendix D, E

After specifying the problem definition and design vision, the actual *designing* starts now with getting inspiration and generating ideas. Several methods and tools were used for this purpose.

- Several brainstorm sessions are kept with different people involved in this project. The members of the supervisory team played a significant role, as orthopaedic instrument builder Frank Jol and fashion designer Jacintha van den Brink. The main outcomes of the brainstorm sessions are shown in figure 72. This overview shows how pride and confidence might be incited, and 'heroes' and other role models play an important role.
- The target group of teenage prosthesis wearers is captured for style and fashion. And so is the trend for Customisation and Personalisation. These collages can be found in the appendices.
- Existing products and techniques are analysed and captured in collages to explore possibilities and serve as inspiration for new product ideas. These collages can be found in the appendices.
- Sketching is also an important association tool to generate and capture ideas. During the course of this project, many ideas sprung. All the sketches and ideas can be found in the appendices, and they will be shown briefly in this chapter by means of a cluster overview.

As mentioned before, the final result of this chapter will be three detailed concepts, with which a second study can be conducted.

CHOOSE DIFFERENT VERSIONS

CUSTOMISE ON PURCHASE

CUSTOMISE BEFORE USE

ADAPT DURING USE

AUTO ADAPT

GRIP & PROTECT

GADGET

IDEA GENERATION

CLUSTERING

Also see appendix F

The core of the vision was to give teenagers pride and confidence about their prosthesis. In a brainstorm session, a clear connection to Customisation was made. That is also why the clusters are focussed around how well the product is adaptable to the wearers wishes and personal style. The clusters mainly differ on when and where the prosthesis can be Customised.

Functionality

There are two additional clusters about the functionality of the glove. One being the 'normal' glove functions *grip & protect*, and the other one includes more *gadget*-like possibilities like an integrated display and mp3 player with a wireless connection to a mobile phone.

Normal glove functionality is mostly focussed around protection and grip. Grip is often created by using a rough material on the part that requires grip; the palm of the hand. Grip always supports the function of holding an item, and this is similar for a prostheses. Protection is a bit more versatile. Gloves might protect against dirt, water, dangerous chemicals, bumping, scratching, temperature, wind and radiation. For a prosthesis, only some of these factors are important, since there is no real hand involved anymore. A prosthesis mainly has to be protected against scratching, stains and wearing.

Ideas for technological and electronic prosthetics are nice since they have an obvious advantage, even for the not prosthesis wearers. A genuine problem in this project is the feasibility. Arm prosthetics is a niche market, and it is questionable how advantageous this technology really is for the prosthesis wearers. The prosthesis gets more vulnerable for bumping, water and dirt, and it is likely to be much more expensive as well. New functions are added but the usability decreases. In other words, the risk for a new product like this is too high, but it might be a consideration for the future.

Choosing Different Versions

Create different versions with varying characteristics, and simply let the wearer choose which fits best.

Customise on Purchase

Let the wearer design their own glove upon purchase, possibly online. Choose colour, material and patterns, or upload your own drawings, to suit every personal style.

Customise before Use

Give the wearer the opportunity to Customise their prosthesis themselves. Provide a tool with which they can adapt the appearance of the prosthesis, by introducing laces or iron-on patches.

Adapt During Use

Product ideas that give the wearer the opportunity to adapt their prosthesis to the situation, for instance by adding more protection and cover when required.

Auto Adapt

Technological advanced product ideas for a prosthesis that automatically adapts its appearance to the context and situation.

Concepts

Eventually, three ideas from three different clusters were chosen to be developed into testable concepts. The idea selection was based on the designers knowledge and experience, and mainly vary on the feasibility and the level of Personalisation to the user's wishes.

Figure 73: Concept design Integro.

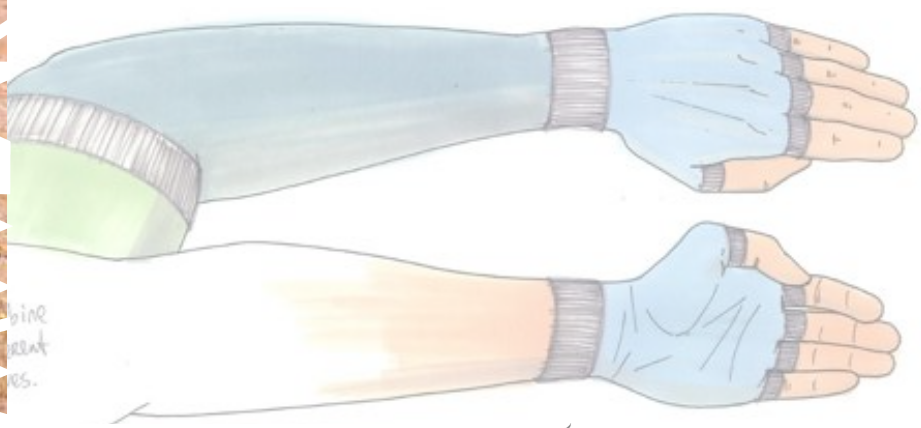
CONCEPT DESIGN

Integro

Different situations, different functions. Adapt your prosthesis to fit your activities.

The Integro is a prosthesis cover that consists of a glove, an arm cover and an elbow piece. Dependent on the situation, the wearer can choose to wear only one or combine them for full functionality (figure 73).

Having one solution with different characteristics for different situations makes the prosthesis a reliable accessory. *Dress* it in chic contexts with the glove, *protect* it during sports or playful situations with the arm and/or the elbowcover, or *show* your prosthesis in a casual environment. This should give the wearer confidence to do whatever he wants without having to worry about the prosthesis.



Prostheses in general are stiff and difficult to manoeuvre in a small glove. The Integro glove has a unique zip from wrist to thumb, to increase the wrist opening, and allow a stiff prosthesis to be inserted. Furthermore, the glove has three main functions.

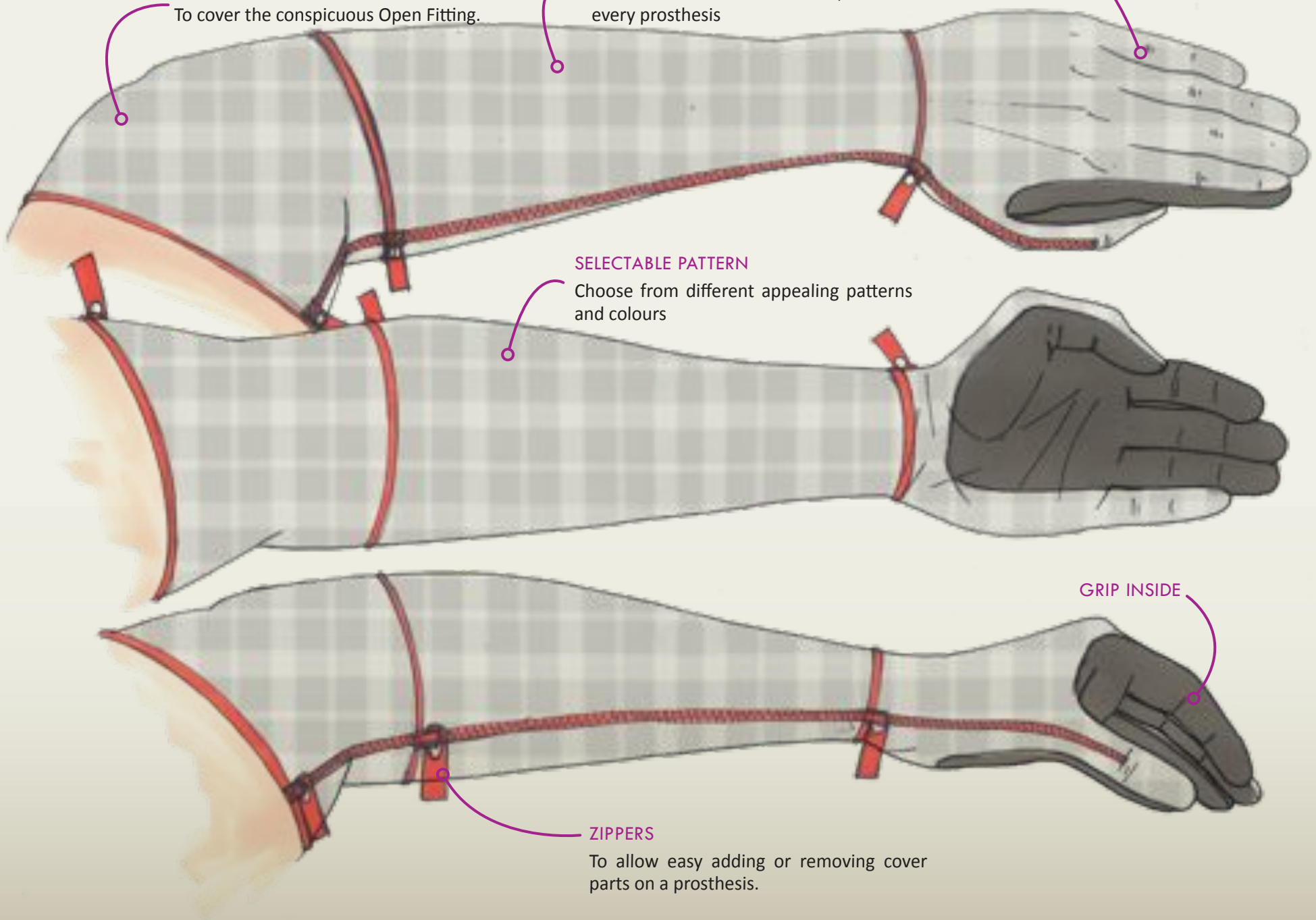
- Protecting the prosthesis from scratches and stains, to increase the durability of the cosmetic glove.
- Providing extra grip in the palm of the hand, to increase the ability to hold items with the prosthesis.
- Changing the appearance of the prosthesis. Using the prosthesis as a fashionable accessory, to increase the acceptation and fascination from others.

The prosthesis is available in various plain colours, and the different parts can be ordered in different colours. This makes the prosthesis even more personal.

Benefits

- Choose the colours from the different pieces to match with your own personal style
- Adapt the product to the activity
- Quickly add and remove parts
- Covers the open fitting
- Adds protection and grip

Detail views



Persona - Alex

Alex is a 14 year old boy. Not very tall for his age, and several of his friends suddenly grew very tall this year. Alex feels a bit insecure about his height now, and he does not like to stand out with his friends in this way. He feels like he must 'work' even harder to be the coolest of his friends group. He likes to wear clothes with a cool brand on it, like Adidas, Nike and Puma.

If someone would ask, he hates school. But secretly he understands the value of good education. He heard that even professional football players need to work hard for their education - 'just in case'. Alex dreams of one day becoming a professional football player too, as good as Christiano Ronaldo, but he realizes the odds are slim.

One other thing, Alex is born with only one arm. He does not feel 'lesser abled' at all, but he sometimes gets the feeling that other people think he is. People look at him differently when he does not wear his cosmetic prosthesis. And he has the competitive feeling he always has to prove his worth more than others.

Most of the time, Alex performs very well without his prosthesis, but for some activities he really needs his prosthesis. For instance playing football is easier when his body is balanced with a prosthesis. But Alex' prosthesis easily gets dirty or damaged, and he has to be cautious for this every time he plays football. Despite all the good efforts, Alex is known for his dirty and damaged prosthesis.

With his new Integro prosthesis glove, he does not have to be that cautious anymore. The glove can be washed just like his normal clothing. The three parts of the glove cover the prosthesis where he wants, and Alex can easily add or remove those parts when he does not need them. Besides, Alex has chosen the colour of the glove himself, and he likes that other people think he is just wearing a fancy glove.

Figure 74: Concept design ArmWear.

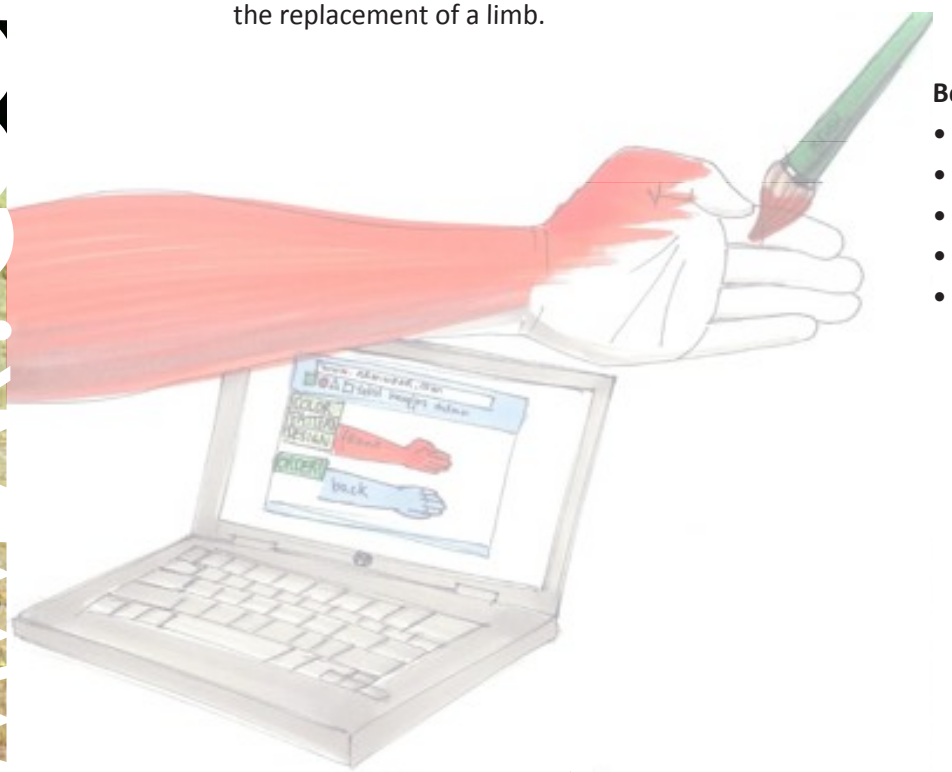
CONCEPT DESIGN

ArmWear

Design your own glove. Customise the appearance to suit your style and personality.

ArmWear is an online service for prosthesis wearers. A web-shop provides the opportunity to design your own custom prosthesis glove (figure 74).

Creating your own designs must provide more affection and pride for the prosthesis, and unconsciously give the user more confidence. A prosthesis must be seen as a beneficial addition to the body, an accessory rather than the replacement of a limb.



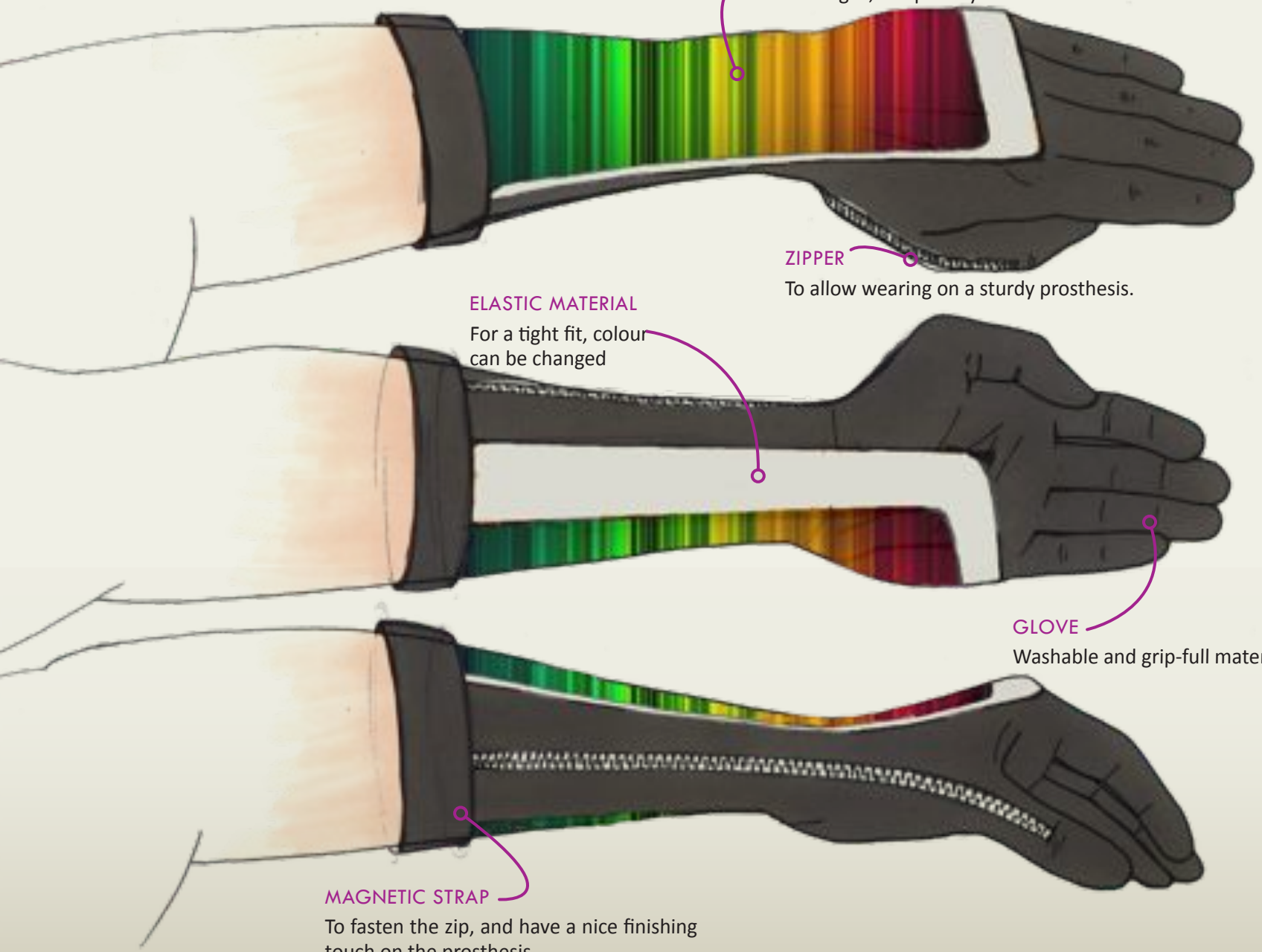
The glove consists of an anthracite basis, on which the user can Customise three textile areas.

- A large white 'design area' can be colour printed with any custom design. The users can fully demonstrate their own graphical and creative skills, or choose from several premade glove designs.
- The user can choose from several colours and fabrics for the details. The details include a thin line around the design area, a brand label and the zipper.
- The grip material on the palm of the hand is also available in different colours.

Benefits

- Design your own glove online
- Proudly display your graphical skills
- Fits with - and emphasises - every personal style
- Custom unique products suitable for low numbers
- Adds protection and grip

Detail views



Persona - Sarah

Sarah is 14 years old, and she thinks of herself as a rebel. Maybe also because she always questions authority, and gets in trouble for her perseverance. She does not really fit with any of the popular girl groups, and instead she turned 'Gothic'. Sarah is a unique human being, not in the last place because she is born with only one arm. Sometimes this makes her feel a bit misunderstood and lonely.

Her parents always wanted Sarah to grow up the way she was born, without a prosthesis. But recently, Sarah decided - herself - to start wearing a cosmetic prosthesis. Sarah has the feeling that people would appreciate her more if she would appear 'normal', with a prosthesis. But now she is not so sure anymore. True, the first impression is quite okay, but at a closer look is a bit awkward and even a bit 'corpse-like'. The colour is a bit off, the material feels cold and unnatural and the hand does not move at all. She would like to cover the prosthesis with a glove, but it is impossible to pull on a normal glove.

Since a few days, she feels very good about her prosthesis. Since her new ArmWear prosthetic glove arrived. A special prosthesis glove that perfectly fits around her prosthesis. But the best thing about it is that she designed the entire glove herself online! The glove fits perfectly with her own clothing style, and she knows for sure that some of her friends will even be jealous of her cool glove.

Figure 75: Concept design Di Guanti.

CONCEPT DESIGN

Di Guanti

Your prosthesis in disguise. Two gloves will make both hands look the same.

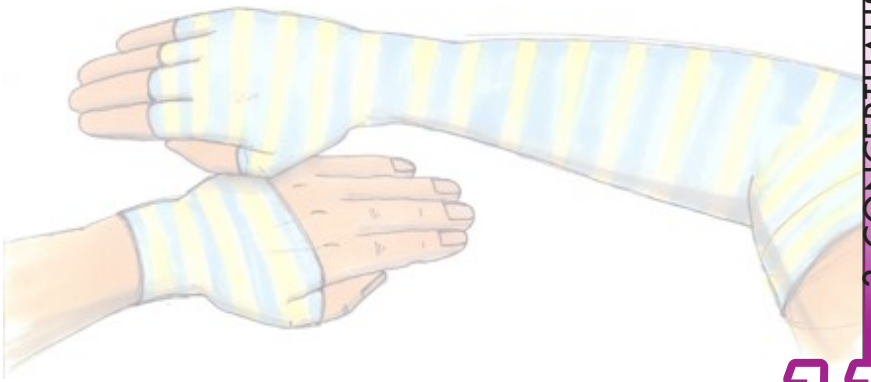
Di Guanti is Italian for 'pair of gloves', because it appears to be a normal pair of gloves, available in several fashionable designs (figure 75).

Anyone can buy and wear these gloves, which multiplies the target group size significantly. Di Guanti is based on inclusive design with special benefits for prosthesis wearers.

- The special opening makes them large enough to wear over a stiff prosthesis.
- Di Guanti will protect the hand - the most vulnerable part of the prosthesis - from accidental bumping and scratching, as well as from stains and dirt.
- Furthermore the glove provides additional grip, increasing the ability to hold and support items. Useful for hands as well as prostheses.
- The gloves are available in several fashionable designs. The user can choose the design he or she likes and feels comfortable with. A design that suits his or her personal clothing style.
- The designs are available for everyone, so prosthesis wearers will not have to feel different when wearing these gloves. The fact that they too can wear two gloves makes their hands similar and thus inconspicuous. The gloves will draw the attention away from the prosthesis.

Benefits

- No 'special' prosthesis product
- Inclusive: large target group
- Choose your between several versions
- Opening gives the impression of uncovered skin
- Adds protection and grip



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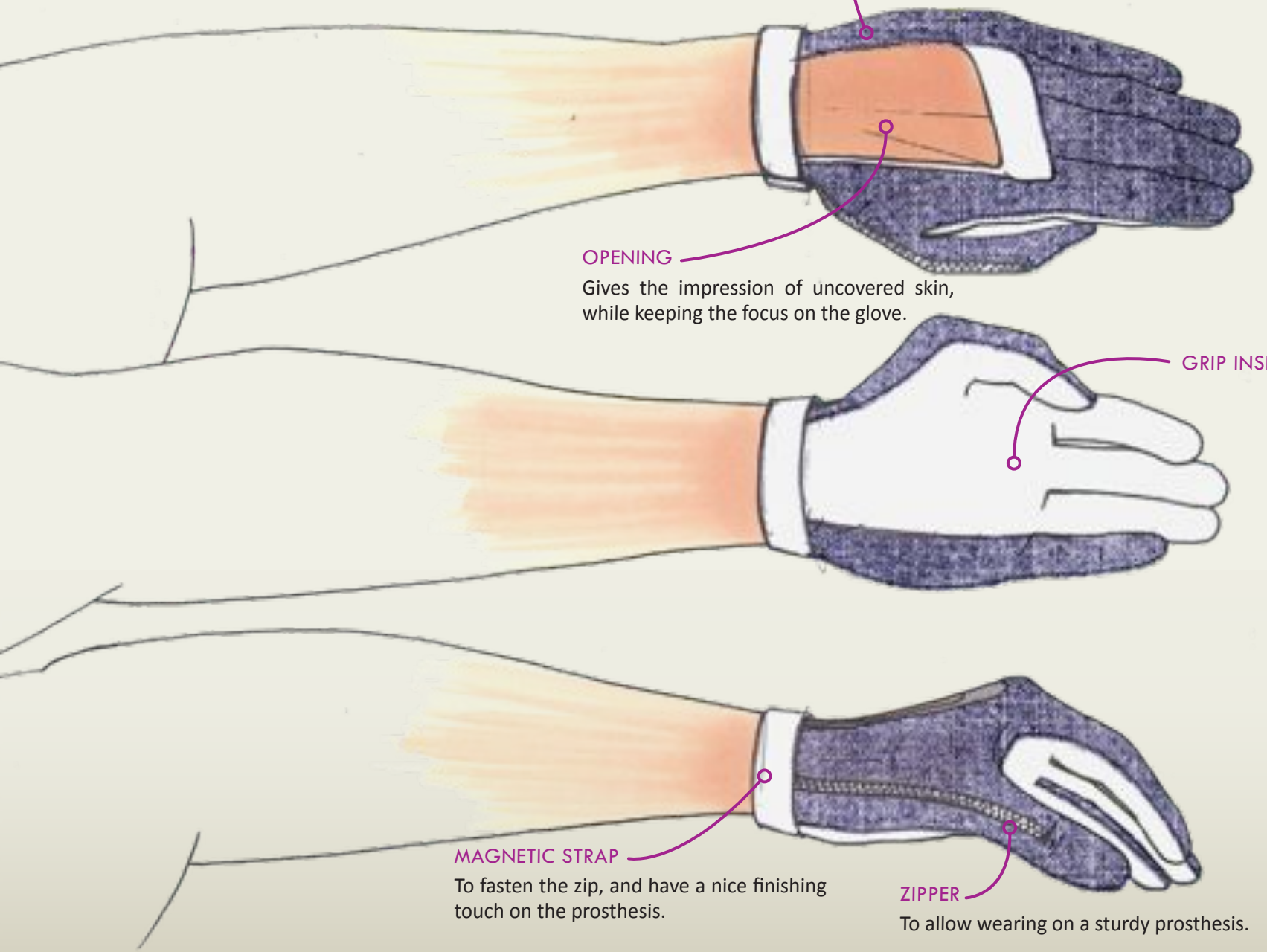
Detail views



Persona - Mandy

Mandy is a 15 year old girl. She is pretty to look at, even though she thinks most other girls in her class are much more beautiful. Sometimes it feels like everybody already has a boyfriend except for her. She secretly has a crush on Bas from the super market, but she is too shy to walk up to him. Like every girl, she is insecure about her body. But not every girl needs to live with only one arm, like her. Mandy is born with a left arm defect, and she sometimes asks God why it had to be her.

Mandy now wears a cosmetic prosthesis, which she thinks is quite okay. It has a skin colour, and looks like the other arm. But one afternoon in the sun makes her skin already much darker than her prosthesis. Let alone a full sunny summer. This is why Sarah does not really like the sun, the summer, swimming, the beach, or any clothing without sleeves. In the winter she can disguise most of her prosthesis quite easily - one time she even tried to wear a pair of gloves, but this turned out to be a disaster - but hot weather forces her to reveal her 'flaw'.

However, since a few days, Mandy received her new Di Guanti pair of gloves. With a glove specially designed to be worn on a prosthesis, to make it a fashionable decoration. An accessory rather than a stupid fake arm. It was a tough choice. But out of a few nice designs, she choose a pair of gloves that fit perfectly with the new white dress she now feels confident to wear.

Figure 76: Everybody wants to be unique, with the confidence to live your life the way you want to.

CONCEPT DESIGNS

CRITERIA

The Product Profile must be 'translated' to get workable design criteria. These criteria mark the outlines of this project: arm prosthetics for teenagers. Any product ideas and design possibilities arising from this project will be measured according to these criteria.

Appearance

1.1 Emphasise arm functions and anatomy

Normal arm anatomy and skin functions must be emphasised in appearance and in function without looking uncanny.

1.2 Humanly shape

A normal hand shape is one of the main prosthesis functions, since it gives the impression of a real hand.

1.3 Fashionable & Personalisable

Teenagers are fashion sensitive, and a product that matches the outfit and the wearer is also less conspicuous.

Activities

2.1 Water & dirt proof

Many daily activities might (accidentally) involve water or dirt, and the product must be able to withstand these conditions.

2.2 Shock resilient

Body movements might involve shocks and bumps from the limbs, as well as accidental bumping, especially during the active teenage years.

2.3 Grip

One of the main functions of a prosthesis is holding and fixing items, therefore sufficient grip must be available.

2.4 Cosmetic glove protection

The current system involves cosmetic gloves, which are expensive and vulnerable to damaging and staining.

Maintenance

3.1 Easy cleaning

Cleaning of the product should be easy, and without much additional effort.

3.2 Quick changing/adjusting

Putting on the new product must be easy and quick, and the product must be adjustable to different situations.

3.3 Independency

Normal maintenance must be doable without any help from others.

Production

4.1 Small numbers

Small production numbers must be feasible.

4.2 Tailor-made

Every prosthesis wearer is different, and so are their bodies. Especially teenagers might grow rapidly. A product must be prepared for this situation.

4.3 Feasibility

A general sense of feasibility should be taken into account to create a market-ready product suitable for the current situation.

General

5.1 Inconspicuous

The product in itself must be inconspicuous when worn by a teenager. Resemblance to familiar objects.

5.2 Applicable to current prosthetics

The current prosthetics situation involves many different similar prosthesis, with slight differences. The product must be applicable to as many as possible.

5.3 Advantageous: inclusive design

The product should provide a real advantage for the wearer above their normal situation. This might even result in a product that is advantageous for prosthesis wearers above normal people.

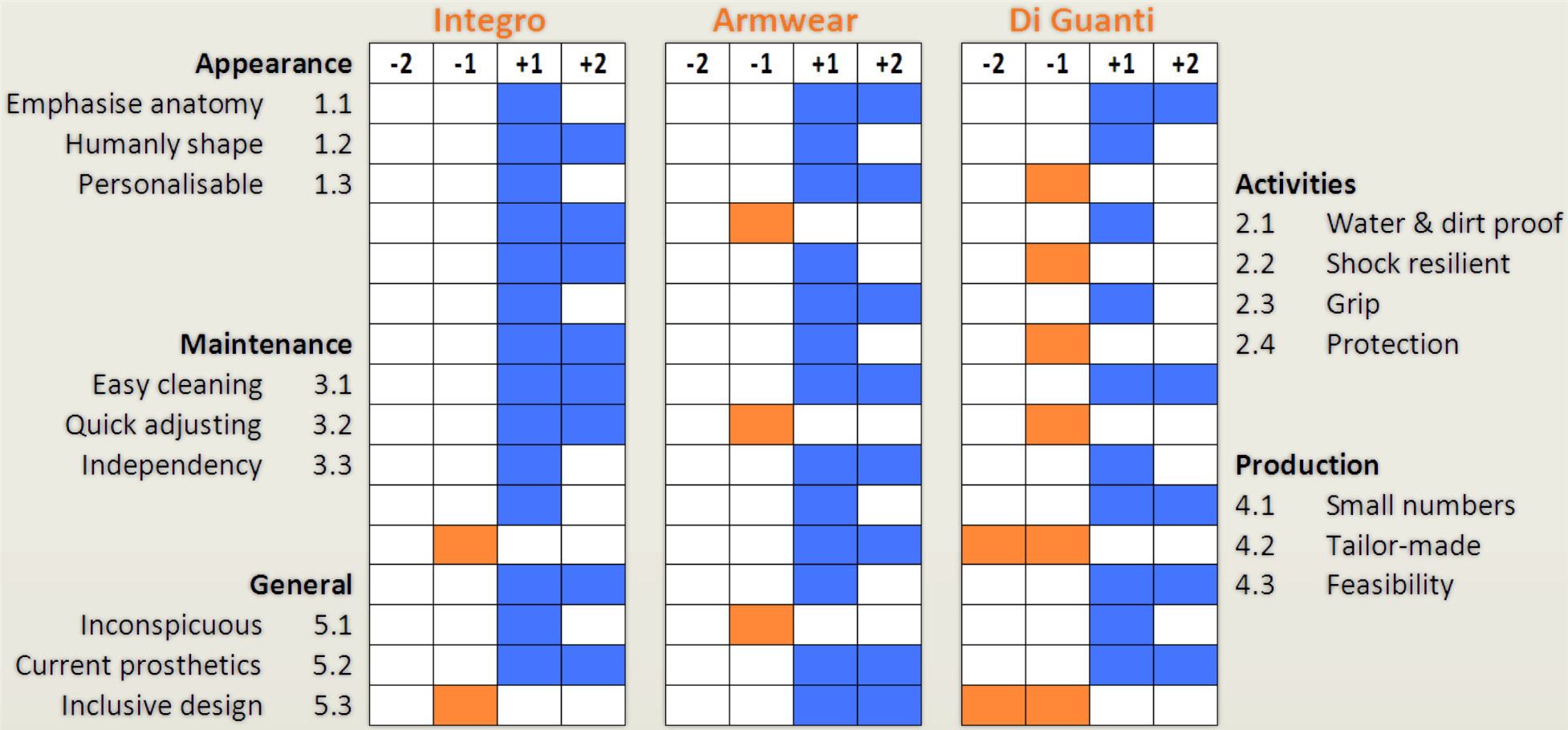


Figure 77: Harris profile of the three concepts. Di Guanti seems to be the least of the concepts.

Harris Profile

Before actually testing the concepts, it is useful to already have an indication about the strengths and weaknesses of each of the concepts. How well do they fit with the criteria of this project? This page contains a comparing Harris profile [43] for each of the three concepts (figure 77).

Appearance

All concepts provide an improvement at the appearance level. Only Di Guanti seems to be a bit less when it comes to personalisable. This concept is available in several designs, and the most favourable design can be chosen. This leaves little room for Personalisation, and the product might increase the 'conveyor belt' feeling.

Activities

Integro seems to be the best of the three when it comes to activities. ArmWear is a Customised design, which makes the threshold to actually 'use' to glove a bit higher. It is too nice to get filthy. The three-piece glove on the other hand is especially designed for activities: it is adaptable, and therefor the threshold is much lower.

Maintenance

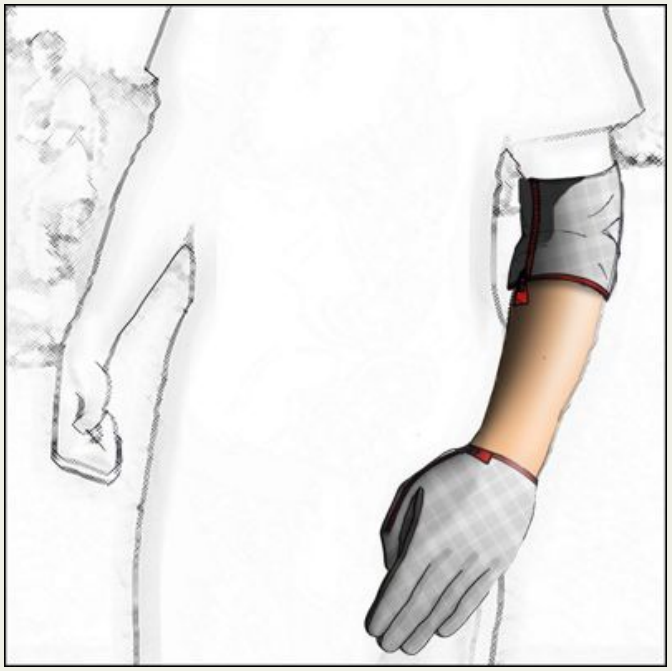
A large advantage of all the concepts is the material. It is a textile glove that can easily be cleaned with normal laundry. Furthermore, only Integro is actually adaptable to the situation. ArmWear and Di Guanti can only be worn or taken off.

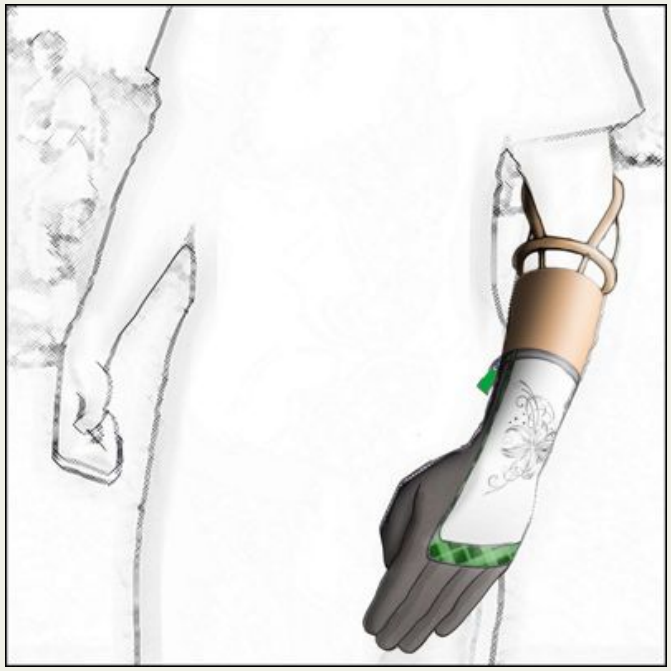
Production

ArmWear is a concept that is meant to be unique and tailor-made. The other concepts are more 'assembly belt' products. On the other hand, Di Guanti is a concept based on inclusive design, and therefore suitable for a much larger target group.

General

All concepts are suitable for existing prostheses, simply because it is a glove that can be worn over all hand-shaped prostheses. Di Guanti is less conspicuous, because of the two gloves on both hands, but leaves the open fitting uncovered. And only Integro has a cover for that open fitting.





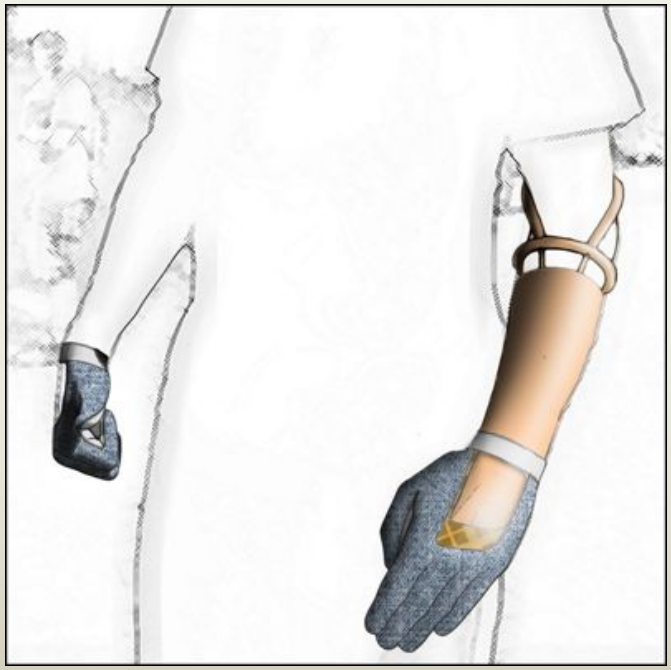


Figure 78: Images of the three concepts: Integro (top left), ArmWear (top right) and Di Guanti (bottom right). The images are created in such a way that they can be used in a second study.

CONCEPT DESIGNS

CONCLUSIONS

The first part of the conclusion of this chapter is the problem definition and the designer's vision.

Teenagers can be very insecure about how they look, and having one arm is a very conspicuous characteristic. Even though they are very well adapted to their situation, others might react surprised or even scared. Wearing a cosmetic prosthesis lowers their feeling of insecurity, even though there are several drawbacks to their prostheses.

Prosthesis wearers only get one prosthesis - for every activity in all situations - while in fact there are situations that require different prostheses with entirely different characteristics. *Sports*, *casual* and *chic* are three important contexts in which people desire a different functionality and appearance from their prosthesis.

Prosthesis wearers too want to belong to a group, but not stand out in the crowd. They want to be unique in the way they like, and not simply because of their amputation. They see their prosthesis not as a replacement of the arm, but as an accessory to the body. A means to express themselves.

Cosmetic gloves are vulnerable, maintenance sensitive and expensive. This makes the cosmetic gloves unsuitable for physical activities that people might want to perform during their occupation, sports, hobbies and daily chores. A new product should make the prosthesis wearers feel proud to wear their prosthesis, and confident enough to act with it.

Vision: Design a product usable on current and future arm prosthetics to give teenager prosthesis wearers the opportunity to be confident and proud to wear their prosthesis.

The idea generation resulted in three concepts suitable for a second study (figure 78), each with their own strengths and weaknesses (figure 77).

Integro

The Integro is a prosthesis cover that consists of a glove, an arm cover and an elbow piece. Dependent on the situation, the wearer can choose to wear only one or combine them for full functionality.

Having one solution with different characteristics for different situations makes the prosthesis a reliable accessory. *Dress* it in chic contexts with the glove, *protect* it during sports or playful situations with the arm and/or the elbowcover, or *show* your prosthesis in a casual environment. This should give the wearer confidence to do whatever he wants without having to worry about the prosthesis.

ArmWear

ArmWear is an online service for prosthesis wearers. A web-shop provides the opportunity to design your own custom prosthesis glove. The glove consists of an anthracite base, on which the user can Customise three textile areas.

Creating your own designs must provide more affection and pride for the prosthesis, and unconsciously give the user more confidence. A prosthesis must be seen as a beneficial addition to the body, an accessory rather than the replacement of a limb.

Di Guanti

Di Guanti is Italian for 'pair of gloves', because it appears to be a normal pair of gloves, available in several fashionable designs. The gloves are made to wear over a prosthesis, but anyone can buy and wear these gloves which multiplies the target group size significantly.

Prostheses in general are stiff and difficult to manoeuvre into a normal glove. Di Guanti has a unique zip from wrist to thumb, to increase the wrist opening and allow a stiff prosthesis to be inserted.

Figure 79: A prosthesis must be suitable to live an active life with.

CHAPTER 4: ARMWEAR ASSESSED

THIS CHAPTER

This fourth chapter will be an assessment of the three created concepts. They will be compared by means of a second PrEmo study amongst teenage prosthesis wearers and their peers. The results of this study will be used to evaluate the concepts, to eventually create the outlines of the final product design.

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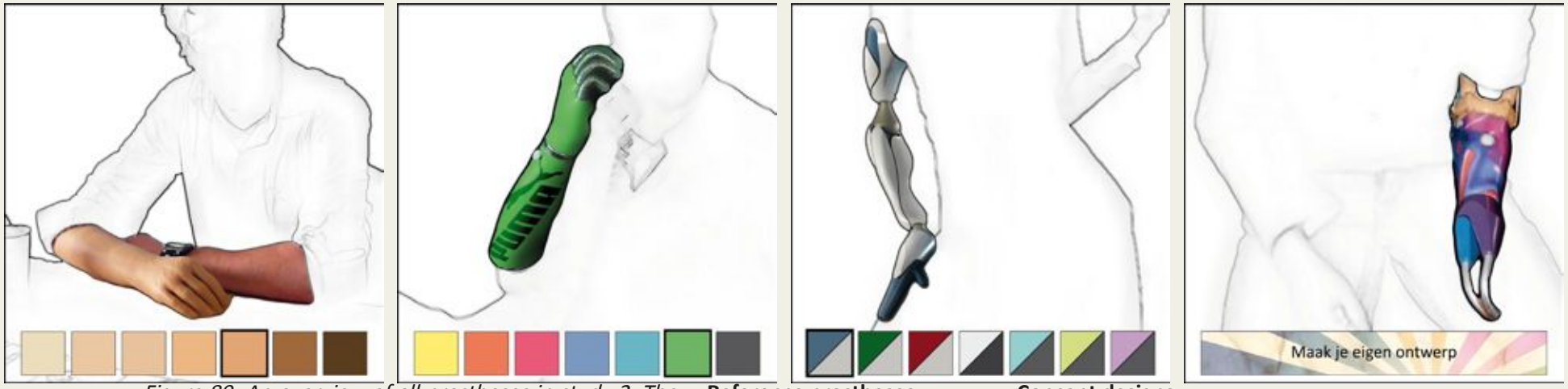
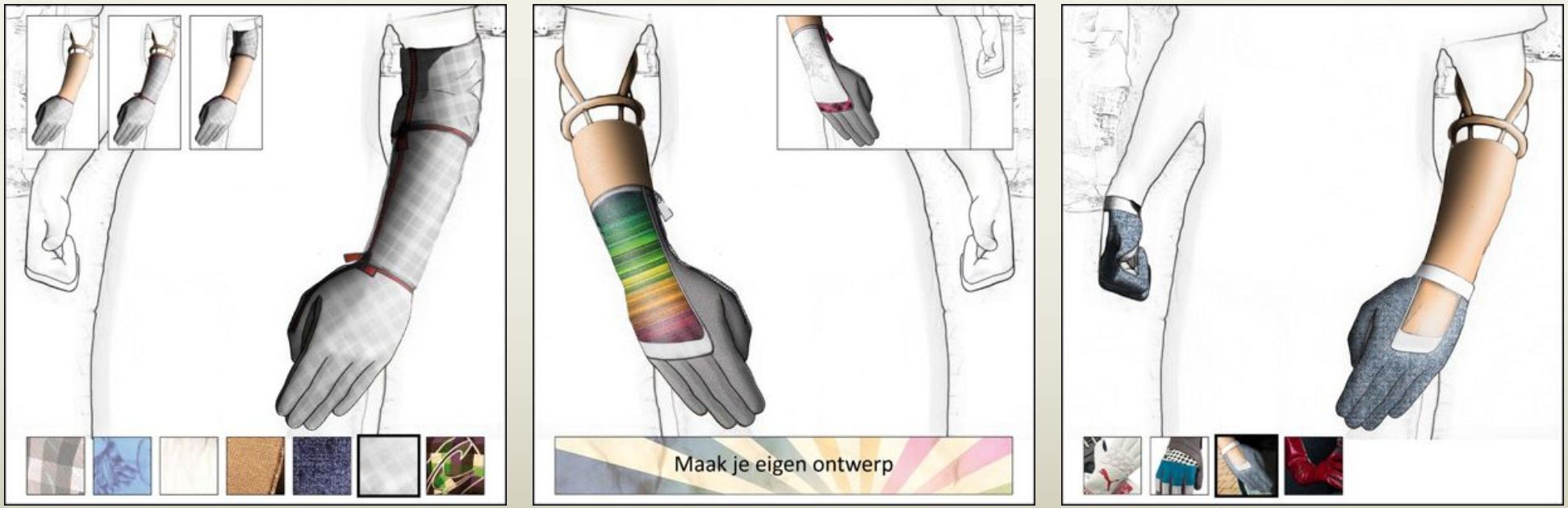


Figure 80: An overview of all prostheses in study 2. The top four prostheses are the reference material, whereas the bottom three prostheses are the concept designs created in this project.

Reference prostheses
1 = Cosmetic glove
2 = Puma green hand
3 = Immaculate
4 = Appealing Prehensor

Concept designs
5 = Integro
6 = ArmWear
7 = Di Guanti



STUDY 2: ASSESSMENT

General Setup

The goal of this second study is to assess the created concepts: to gain insights into the emotional values and the underlying concerns that adolescent arm prosthesis wearers and their teenage peers have towards the created arm prostheses concepts as well as a few reference prosthetics. Each participant will be asked for their response towards images of seven arm prostheses with diverging characteristics.

Study 2 will focus on capturing the emotions that the involved user groups feel towards different prosthetics. The products will be compared with the PrEmo tool through an online questionnaire, with courtesy of the SusaGroup. In addition to the emotions, participants can also comment freely on the shown prosthetics.

In addition to the PrEmo test, the opportunity occurred to let a group of teenage peers to create their own design for the ArmWear concept.

Participants

The participants will consist of two groups of people with different interests towards prosthetics. The teenage prosthesis wearers themselves, and their peers. Study 1 involved prosthetics professionals as well, but the focus shifted to the target group 'teenagers' to test the concepts. A total of 32 teenagers participated.

The prosthesis wearers were contacted with invitations, kindly send by the rehabilitation clinic '*De Hoogstraat*' in Utrecht to suitable people in their patient pool. In addition to this, also the prosthesis wearers who already participated in study 1 were asked to participate.

To reach the teenage peers, a secondary school in Montfoort was contacted. This resulted in the participation of a class of 27 first year students from the '*Wellantcollege*'. As a result, most participants are teenagers in the target group of 12 to 14 years.

Products

The seven prostheses in this study are (figure 80): the three concept designs, a regular cosmetic glove, the Appealing Prehensor, the Immaculate and the Becker red hand. The becker red hand was transformed for this experiment in the Puma green hand, to measure the effect of a popular brand name (figure 81).

Furthermore, the Customisation possibilities of each of the prostheses is emphasised and made credible with an overview of design possibilities (figure 80). For most prostheses, it are just a few squares with a colour, but it can also vary in material of show a complete design. For two prostheses this did not cover the possibilities, and the overview is transformed into the message: "create your own design".

Similar to study 1, the prostheses are shown with one image per product (figure 80). The images must be comparable in style in order to reduce biasing. An image composition is chosen that shows the prosthesis in use. To focus only on the prosthesis, the context is transformed into a wire frame. This also increases the possibility to identify with this 'anybody'. Each of the images is created in a decent resolution (800x800 pixels), and shows the prosthesis semi-centered.

Data

The data in study 2 is visualised with a product space, and explained further with several bar graphs in combination with the summarized comments. Furthermore the data is analysed for significant values with several statistical methods in PASW Statistics 18 (formerly known as SPSS).

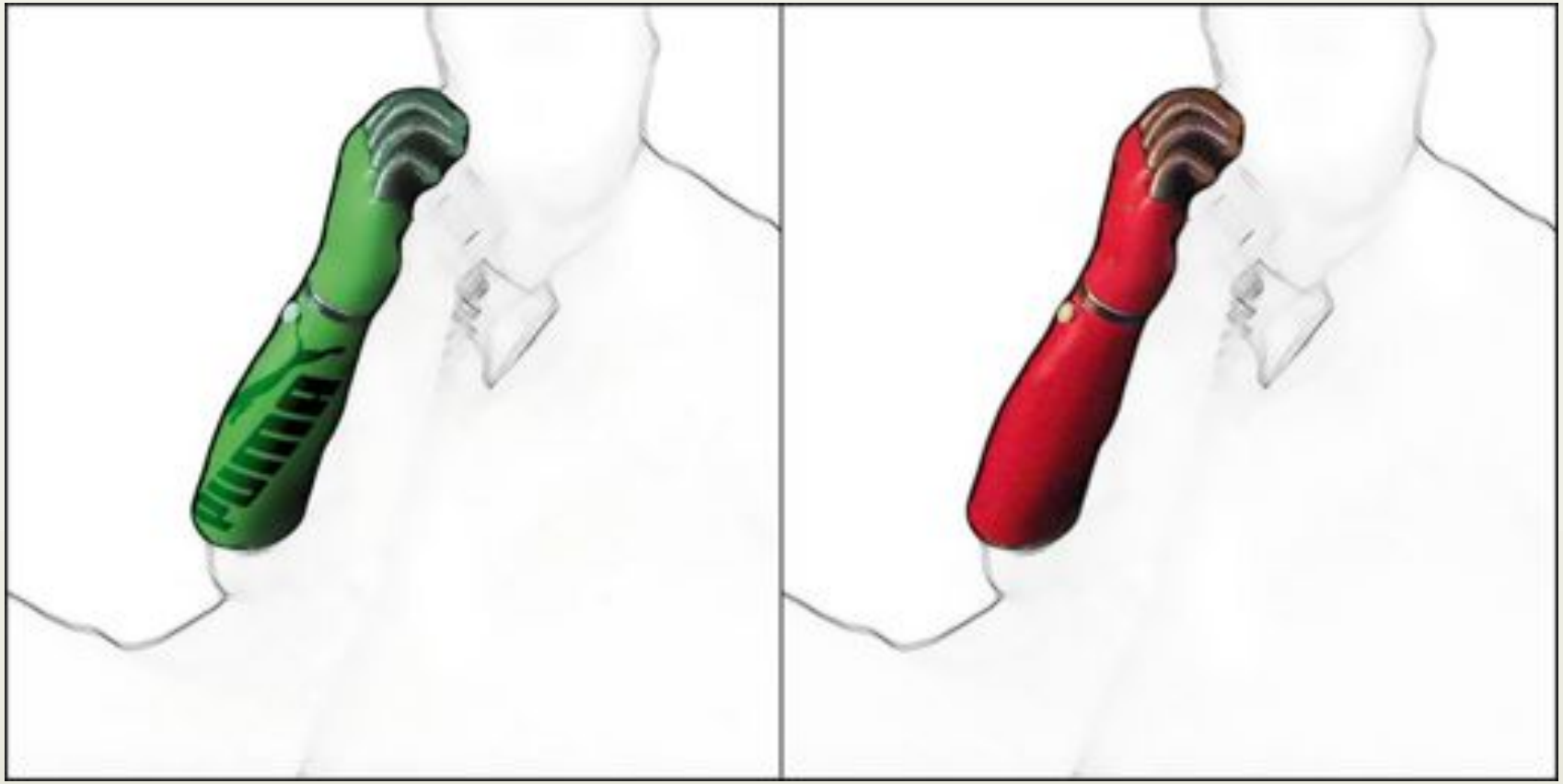


Figure 81: The participants were also asked to choose one of these two prostheses. Both prostheses are the same, but the green arm is now a Puma prosthesis. The popular brand is added in Photoshop. The red hand is already assessed in study 1, where - especially the prosthesis wearers - were extremely negative.

STUDY 2: ASSESSMENT

RESEARCH SETUP

Research question

What emotional responses do the teenage prosthesis wearers and their peers have towards the three arm prosthesis concept designs, and how does this relate to the existing prostheses?

Approach

In this research, the participants are shown images from diverging arm prosthetics, and are asked to record their emotional response in an online PrEmo questionnaire.

The participants will be selected in two groups with different interests towards prosthetics; the teenage prosthesis wearers and their peers. The aim is to approach at least 10 participants in each interest group to obtain usable and comparable data.

The seven compared products (or stimuli) are presented in random order, and so are the emotion animations.

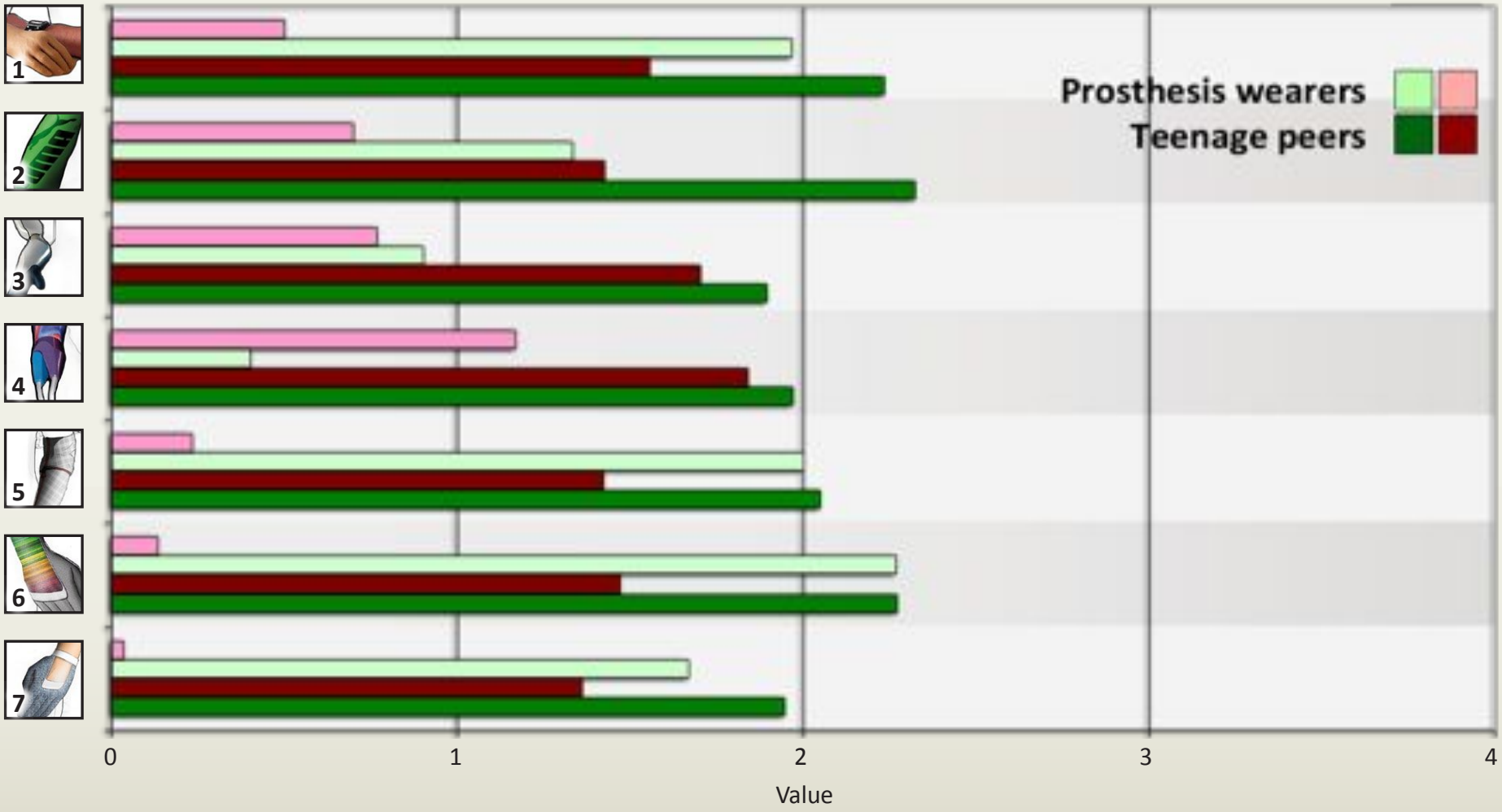
Results

The obtained emotional data of each of the prostheses will be visualised in bar graphs, giving a clear view on the differences in the emotions involved. More conclusions can be drawn from the differences in emotions within each prosthesis, and from the differences between the two participant groups.

The data will also be visually displayed with PASW Statistics 18 (formerly known as SPSS) in a product space. This is a two-dimensional scale of the emotions, on which the products can be positioned. The position and distance show how the product is related with the different emotions.

Significant quantitative differences are unlikely to be found with this small number of participants, nevertheless it will be given a closer look. With a comparisons between groups and between products.

Figure 82: The mean scores for positive and negative emotions, compared by product and participant group. The six positive emotions combined is shown in green, red is negative.



STUDY 2: ASSESSMENT

RESULTS

Also see appendix G

For each prosthesis, the participants were asked to rate how well six positive and six negative emotions (figure 51) fit with the product, with a score from 0 to 4.

When looking at the data, clear differences in the emotional perception of the different prosthesis can be discerned (figure 82, 83), as well as differences between the different participant groups (figure 82, 84).

- The three concepts (5, 6, 7) get very positive emotional scores, especially amongst the prosthesis wearers. The prosthesis wearers rate these concepts with the least negative emotions, and the most positive emotions of all tested prostheses.
- Despite all the assumptions, the cosmetic glove (1) also gets a lot of positive responses. People do appreciate the inconspicuousness of the skin colour of this prosthesis. A different image was used than in study 1, and now especially the teenage peers responded much more positive.

One of the assumptions from study 1 was the positive effect of a brand(name) on a prosthesis. In study 1, the Nike sports leg (figure 61) was perceived extremely positive. The first study also contained the Becker red hand (figure 55, 56). This prosthesis was perceived very negative. From all prostheses, the prosthesis wearers were the most negative about this one.

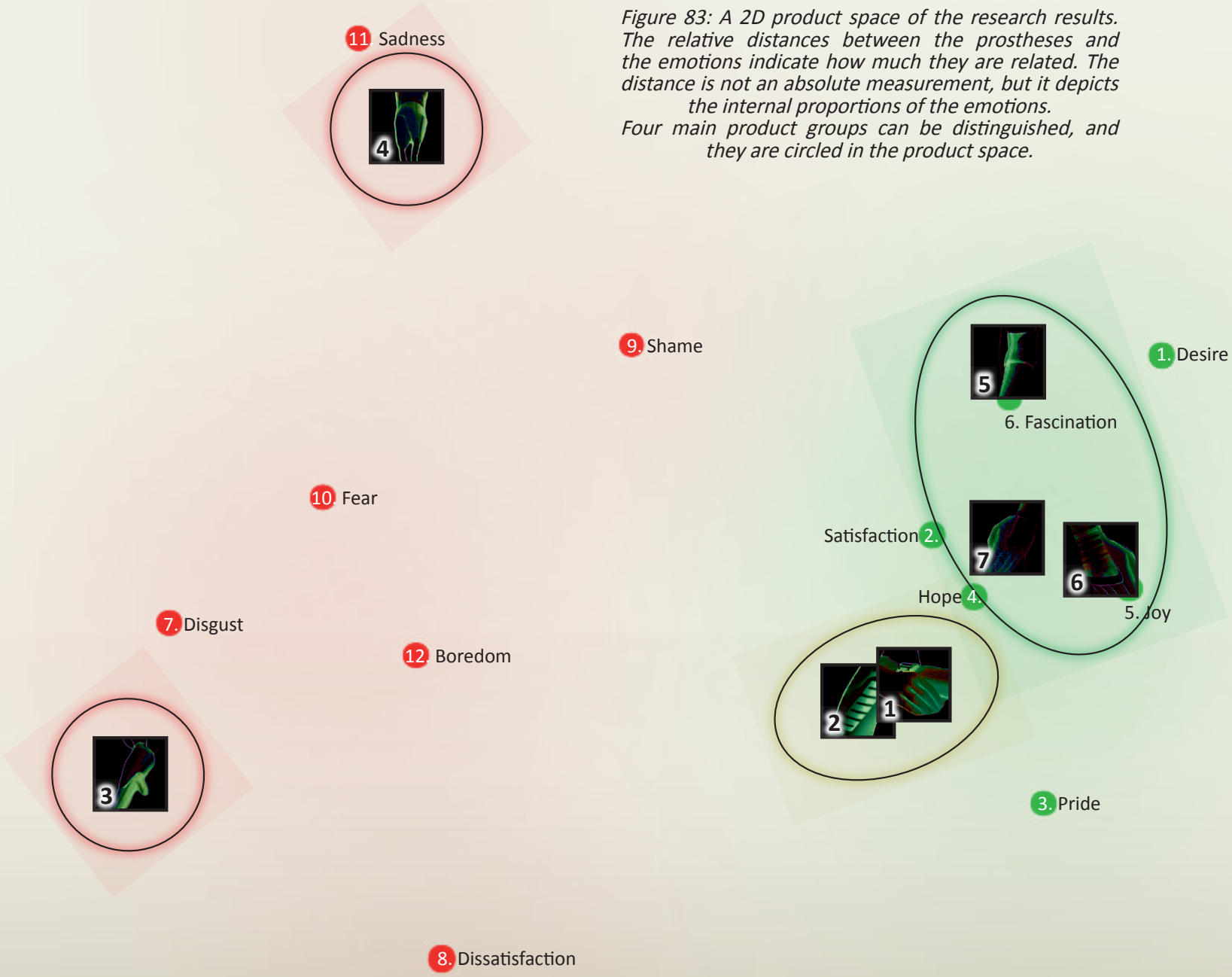
This second study will contain an experiment to measure the effect of a brand name on a prosthesis. The original red hand was coloured green with Photoshop and now contains a large brand name (Puma) that will be featured in this study (figure 81).

- The 'Puma green hand' (2) was also perceived quite well, almost as good as the cosmetic glove. Especially the teenage peers, but even the prosthesis wearers reacted positive to this 'new' prosthesis.

In contradiction to Study 1, there were only few prostheses that evoked mixed emotions.

- Only one prosthesis evokes different responses amongst the two participant groups: the Appealing Prehensor hook (4). This prosthesis is also perceived to be the most negative. The peers show as much negative as positive emotions, but the prosthesis wearers are clearly more negative about this prosthesis. The only hook prosthesis is again the prosthesis with the most negative responses, and the only prosthesis with more negative than positive emotions.
- The Immaculate (3) is assessed quite neutral, with almost equal negative and positive responses from both participant groups. This prosthesis was also featured in study 1, where it was perceived a bit more positive by the peers, and a bit more negative by the prosthesis wearers.

Figure 83: A 2D product space of the research results. The relative distances between the prostheses and the emotions indicate how much they are related. The distance is not an absolute measurement, but it depicts the internal proportions of the emotions.
Four main product groups can be distinguished, and they are circled in the product space.



Product space

With the PrEmo data, a correspondence analysis is performed, resulting in a two-dimensional product space of the products and emotions (figure 83 and 84). The position of the product in relation to the emotions shows the relation with these emotions. The smaller the distance, the more related the two factors are. The distance is not an absolute measurement, but it merely depicts the internal proportions of the emotions.

The positive (green) and negative (red) emotions are typically arranged in two groups, which results in a horizontal distinction between positive and negative emotions. Within this matrix, several groups of prostheses with similar emotional responses can be distinguished.

- The three concepts Integro (5), ArmWear (6) and Di Guanti (7) are placed the farthest to the right, the positive green area. These prostheses were also perceived with the most positive and the least negative emotions.
- Two prostheses are also judged to be quite positive, and are therefore placed very close to the green area. In fact, the cosmetic glove (1) and the Puma green hand (2) are assessed quite similar, since they even overlap each other.
- This leaves two prostheses placed at the left. The Immaculate (3) and the Appealing Prehensor (4). These prostheses showed the most negative and the least positive emotions of all seven prostheses, and are therefore placed in the negative red area. These prostheses both also have a large deviation from the horizontal axis, which indicates more mixed emotions within this prosthesis.

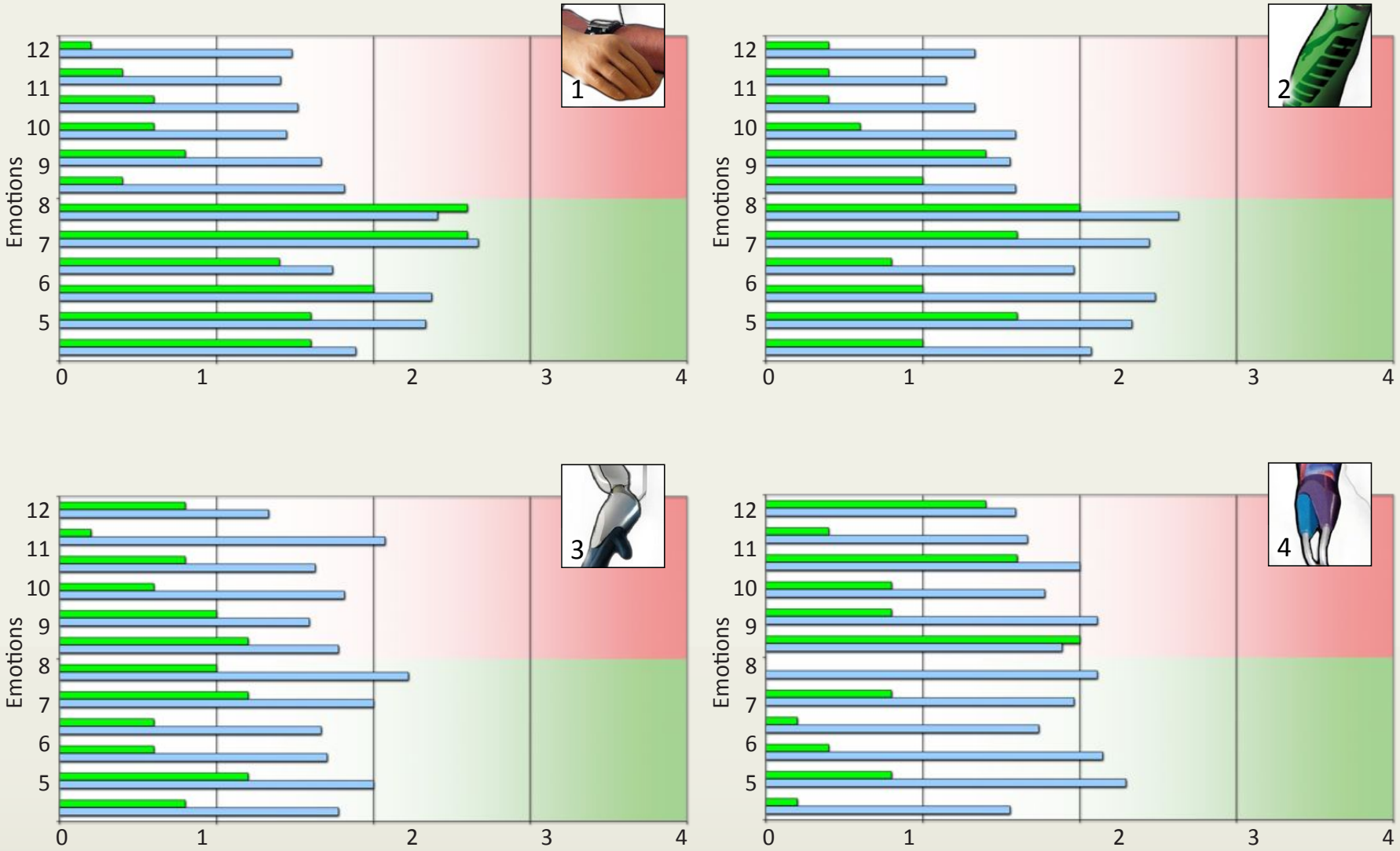


Figure 84: An overview of the mean results of the 12 emotions from the different participant groups for the 4 reference prostheses.

Legend: *Prosthesis wearers, Teenage peers*

Emotions:

1. Desire	*2. Satisfaction*	*3. Pride*	*4. Hope*
5. Joy	*6. Fascination*	*7. Disgust*	*8. Dissatisfaction*
9. Shame	*10. Fear*	*11. Sadness*	*12. Boredom*

STUDY 2: ASSESSMENT

REFERENCE PROSTHESES

Cosmetic glove (1)

- ...is perceived positive by all participants, even the peers. This might be the result of a different image than study 1. This image was of much better quality, and did not show the open fitting. Prosthesis wearers will be affected less by this, since they already know the prosthesis from experience. Wearers show especially much joy and fascination.
- ...gets dichotomous comments. One group likes the skin colour since it is natural and inconspicuous, while the other group thinks that the skin colour is just not the same as a real hand, and the differences are too obvious.

Prosthesis wearer: "The only bad thing is that people will still stare, only now because it looks like a hand that can not move"

Teenage peer: "This one is cool because it looks just like the other arm. Still I would choose something different, it's just what you prefer"

Huseklepp's Immaculate (3)

- ...shows equal amounts of positive and negative emotions in both groups. The emotional response is neutral.
- ...is thought to have a weird shape, since it does not resemble a real hand. Responses differ from 'scary' to 'super-ugly', and most participants indicate that they would never wear such a prosthesis.

Prosthesis wearer: "Weird and fake and inhuman"

Teenage peer: "It's a bit scary. I think the shape should be different... and a different colour with little hearts"

Puma green hand (2)

- ...shows the least differences between the group responses, and is suddenly one of the most popular prostheses in the study.
- ...was loved because of the popular brand. The teenage peers were lyrical about this prosthesis, but the prosthesis wearers were a bit more distant. They thought the prosthesis was too conspicuous and did not like the fingers. The prosthesis wearers were a bit more practical in their comments.

Prosthesis wearer: "It is too conspicuous and why Puma?"

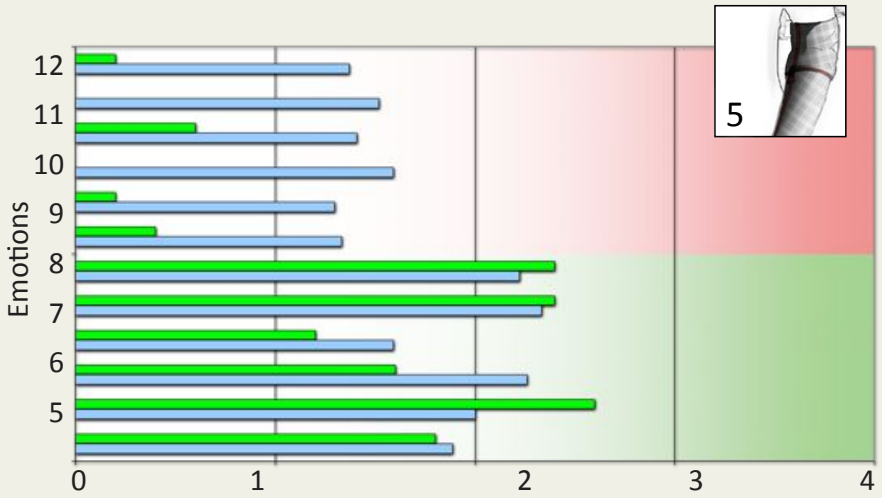
Teenage peer: "This one is original! But I don't like the fingers, they look like tubes or something..."

WILMER© Appealing Prehensor (4)

- ...has the most mixed emotions from all prostheses. The teenage peers show an equal amount of positive and negative emotions, while the prosthesis wearers have more negative emotions. High boredom, fear and disgust, but the other negative emotions are quite low. It is also remarkable that the prosthesis wearers show no fascination at all.
- ...has very clear unanimous comments, in contradiction to the emotional responses. The responses are overwhelmingly negative. Associations with pirates and the disgust for hooks are obvious. Despite all the efforts, many participants still look only at the presented colours, and not at the other possible appearances.

Prosthesis wearer: "I like that you can make your own design, but I just don't like the hook"

Teenage peer: "Gross! That's plain ugly. Like a coloured version of Captain Hook"



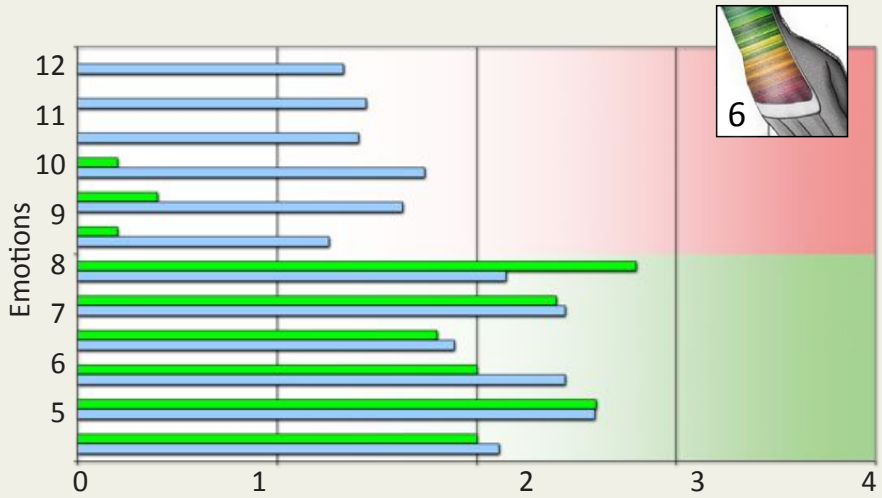
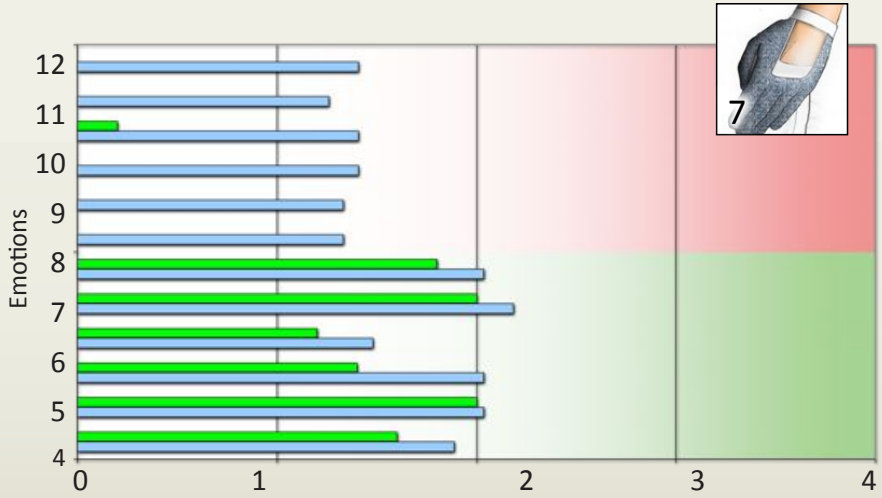


Figure 85: An overview of the mean results of the 12 emotions from the different participant groups for the 3 prosthesis concepts.



Legend: *Prosthesis wearers, Teenage peers*

Emotions:

1. Desire	*2. Satisfaction*	*3. Pride*	*4. Hope*
5. Joy	*6. Fascination*	*7. Disgust*	*8. Dissatisfaction*
9. Shame	*10. Fear*	*11. Sadness*	*12. Boredom*

STUDY 2: ASSESSMENT

CONCEPT DESIGNS

Concepts

The three concepts all get very similar emotional responses. The teenage peers show slightly more positive than negative emotions, but the prosthesis wearers are the clearest in their response. They show almost no negative emotions, and very high positive emotions.

Integro (5)

- ...gets positive responses like the other concepts. The average emotional values would fit right between the other two concepts. Although Pride is a bit lower with this prosthesis.
- ...is considered a bit 'weird' and 'funny'. Probably because this is a glove in a completely new form with detachable pieces. People have never seen anything like this, and have to get used to it. However, participants do appreciate this feature. Many participants still judge this prosthesis merely on the visible colours, and not on the other possibilities.

Prosthesis wearer: "At first I had my doubts about covering my prosthesis, but now I'm actually curious about a cover for my Open Fitting"

Teenage peer: "Nice design, especially the fact that you can remove or add pieces"

ArmWear (6)

- ...gets very positive responses. The most positive emotions of all prostheses, and only very little negative emotions. Especially Fascination shows a high peak of almost 3. Of the three concepts, ArmWear evokes the most pride amongst the participants. And it is arguable that a true own design will evoke even more positive emotions.
- ...also gets very positive comments. Many people like one of the two designs, and other people would really like to try and design their own glove. Participants appreciate the fact that they can cover a prosthesis with a glove to appear normal.

Prosthesis wearer: "I think it is fun to design your own prosthesis, and on top of that you get a unique prosthesis"

Teenage peer: "I really like how it looks, and if I could make my own design I would definitely choose this one"

Di Guanti (7)

- ...has the least positive emotional responses of the three concepts, but also the least negative. Prosthesis wearers show almost no negative emotions at all. This might be due to the fact that this concept shows the most resemblance to a normal pair of gloves.
- ...gets a lot of mixed comments. Many comments narrate about 'ugly', 'not so nice' and the fact that it is 'just a glove'. But this is actually exactly the function of the concept. Other people think this concept is 'very nice', and one of the variants shows a Puma glove which is highly appreciated.

Prosthesis wearer: "I like to play football, and this concept would be very suitable for that"

Teenage peer: "This is just a glove..."

Comparison	**Cosmetic Glove**	Puma **Green hand**	WILMER **Appealing Prehensor**	Huseklepp's **Immaculate**
Concept **Integro**	*None significant differences*	*None significant differences*	**More** + Positive + Fascination **Less** - Negative - Disgust	*None significant differences*
Concept **ArmWear**	*None significant differences*	*None significant differences*	**More** + Positive + Desire, Satisfaction, Pride, Fascination **Less** - Negative - Disgust, Fear	**More** + Positive + Satisfaction, Pride, Joy

Figure 86: This tables gives an overview of all the different emotions that showed significant differences in a pairwise product comparison between the concepts and the reference prostheses. Since the only significant differences are positive in favour of the three concepts, these are indicated in green.

STUDY 2: ASSESSMENT

SIGNIFICANCE

All the values for the separate emotions are compared pairwise by product and by group, with a Multi-Analysis of Variables (MANOVA), to find out if the observed differences are significant or just coincidental. This analysis is performed on the combined results of all 32 teenage participants (figure 86), as well as for each group separately.

Separating the groups caused two problems: the number of prosthesis wearers was too low to find any significant differences for that group, while the teenage peers showed too little variation in their responses to find any significant differences either. It was almost like they did not fill out the research in a correct manner. This will be further argued in the discussion. These problems also caused the between groups comparison to result in no valuable conclusions.

Between products

The goal was to design a prosthesis that would appeal to teenagers. A 'cool' prosthesis which they can be proud of. Study 1 showed the cosmetic glove as one of the most positive arm prostheses, and a significant improvement with regard to this prosthesis would be desirable. The visual data on the previous pages showed promising results, but the slight improvements were not big enough, and the numbers not large enough to show significant differences in comparison to the three concepts. Coincidence can not be excluded here.

Branding

An improvement for the Puma green hand was expected in pertaining to the Becker red hand, but the eventual popularity was even a bit unexpected. Recent research has proved the value and effect of branding; especially women showed significant effects when wearing clothing with a popular brand name. They became more self-confident and performed better at cognitive tasks [6].

The Puma green hand scored very good, comparable to the cosmetic glove. Therefore no significant improvements pertaining (one of the) concepts could be determined.

The other two reference prostheses were the Appealing Prehensor, a hook prostheses that scored quite negative in study 1. And the Immaculate, a futuristic form giving project, that scored mediocre in study 1, after high expectations beforehand. This time the Immaculate was pretended to be customisable as well, to gain interest. However, again these not hand-shaped prostheses scored very negative. They were the two least popular prostheses of study 2. The visual data on the previous pages showed large differences between those prostheses and the other five products, and many of those differences turned out to be significant.

The cosmetic glove and the Puma green hand were also compared to the Appealing prehensor and the Immaculate. They too showed significant improvements pertaining the Appealing Prehensor - less than the three concepts - but they showed no significant differences with the Immaculate, while ArmWear and Di Guanti did.

Of the three concepts, ArmWear shows the most demonstrable improvements from the Appealing Prehensor and the Immaculate, so in comparison to the reference prostheses. ArmWear can be determined as being significantly the best concept, and even slightly better than the cosmetic glove.

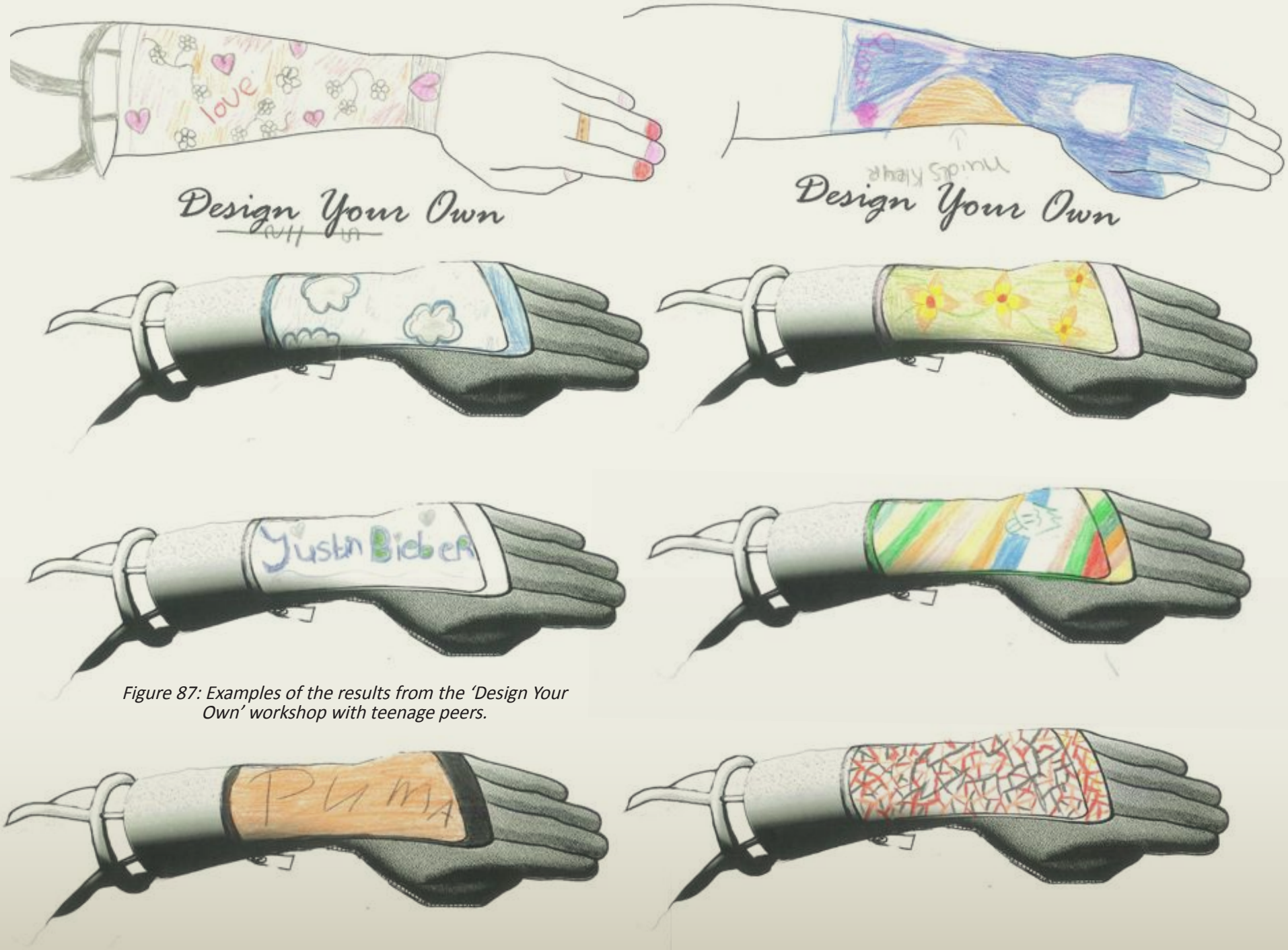


Figure 87: Examples of the results from the 'Design Your Own' workshop with teenage peers.

STUDY 2: ASSESSMENT

WORKSHOP: DESIGN YOUR OWN

A class of teenager students at the Wellantcollege in Montfoort was willing to participate in a workshop to 'Design You Own' prosthesis. Each student was first educated about arm prosthetics, and afterwards they received a drawing sheet with a blank arm and a blank ArmWear prosthesis (figure 90).

It was up to them to draw and colour the prosthesis to their own wishes. Everything is possible, which also showed in the results (figure 87).

Every design turned out to be unique, even if two students copied each other. They tried to make their design even more unique by including aspects of themselves. A very clear example is the 'FC Utrecht' prosthesis made in resemblance to the football club (figure 88). Other examples are a 'Justin Bieber' prosthesis, named after a teenage superstar. Some teenagers like to include their own creations in the prosthesis: smileys, characters and other creations of their own design.

These results confirm the earlier brainstorm sessions about pride and confidence (figure 72). Creating your own design makes a product that you can be proud of. And creating your own drawing also includes your handwriting, and makes a prosthesis even more unique and personal.

Figure 88: A teenage football fan designed his own prosthesis with the logo and colours of his favourite football club FC Utrecht (inset).

Figure 89: An artist impression of the best features of the prostheses in study 2 combined. This impression contains a popular brand name (Puma green hand), a customisable glove (ArmWear) and an elbow piece to cover the Open Fitting (Integro).

STUDY 2: ASSESSMENT

CONCLUSIONS

Natural shape

As conjectured in study 1, a natural shape is important. The two prostheses with an artificial shape - the Immaculate and the Appealing Prehensor - are judged most negative, and the participants point to the artificial shape as the cause.

Another issue is the Open Fitting. This type of fitting solves many comfort issues in comparison to a conventional fitting, but the drawback is that it disturbs the natural shape of the arm. Integro provided a solution with the elbowcover, an appreciated feature.

Brand

Popular brand names can make a huge difference in appreciation and self-confidence. The Puma green is judged much more positive than its unbranded red equivalent. Especially the teenage peers unanimously choose the Puma hand, and their comments clearly mark the brand as the cause.

For further development a cooperation with a strong and popular brand could be advantageous, but the realistic question is which brands would like to be associated with prostheses. Next to that, brands also appeal to a specific (core) target group, which could narrow down the already small target group of teenage prosthesis wearers.

Conservative vs. Alternative

Despite all assumptions and theories about skin coloured prosthetics, the cosmetic glove is again assessed as one of the popular prostheses in the study. In their comments, a large group of respondents appreciates this cosmetic glove for its natural appearance, while another large group has their doubts about the effectiveness of the skin imitation.

There seems to be a dichotomy in participants: a group would still choose a conservative skin coloured prosthesis, while another group really appreciates the option of a customisable coloured alternative.

Customisation

The ArmWear concept is very much appreciated for its customisation. Two important issues are the time and accessibility for designing your own prosthesis.

Another limiting factor could be the users creativity and the available tools. Freely drawing or designing your own prosthesis is simply not suitable for everybody. The majority will need appropriate inspiration and assistance.

Designing your own prosthesis is expected in revalidation centres; places that are associated with prosthetics. Another logical option seems to be an online website, which is easily accessible for everybody at all times. People expect the customisation to take a few hours, but when you are able to do this at home it could take up to a few weeks.

Concept improvements

The results from study 2 indicate that the three concepts are highly appreciated especially by the prosthesis wearers. The product space (figure 83) even shows that the three concepts evoke the most positive emotional responses of all tested products, even better than the cosmetic glove. From that point of view, the concepts already succeed in the goal of improving current prosthetics.

With the results from study 2, the best features of each concept will be combined into 'the perfect cool teenager arm prosthesis', of which an artist impression can be seen in figure 89. This impression shows the ArmWear glove, the Integro elbowcover, branded by Puma. Chapter 5 will be dedicated to the elaboration and evaluation of the final product design.

*Figure 90: Now it's time to finish and test **my own** design*

CHAPTER 5: ELABORATED & EVALUATED

THIS CHAPTER

This fifth and final chapter will be about elaboration and evaluation of the final product design. The final design will be explained in detail. This chapter will include subchapters about colour, materials, production, and eventually a working prototype to allow evaluative usability testing of the new and improved arm prosthesis enhancement.

The conclusions, recommendations and evaluations of this third study will conclude the final chapter and therefore the entire project. As a bonus, a summary is added at the end of this chapter, merging all conclusions into a logical story.

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CHAPTER 5: ELABORATED & EVALUATED

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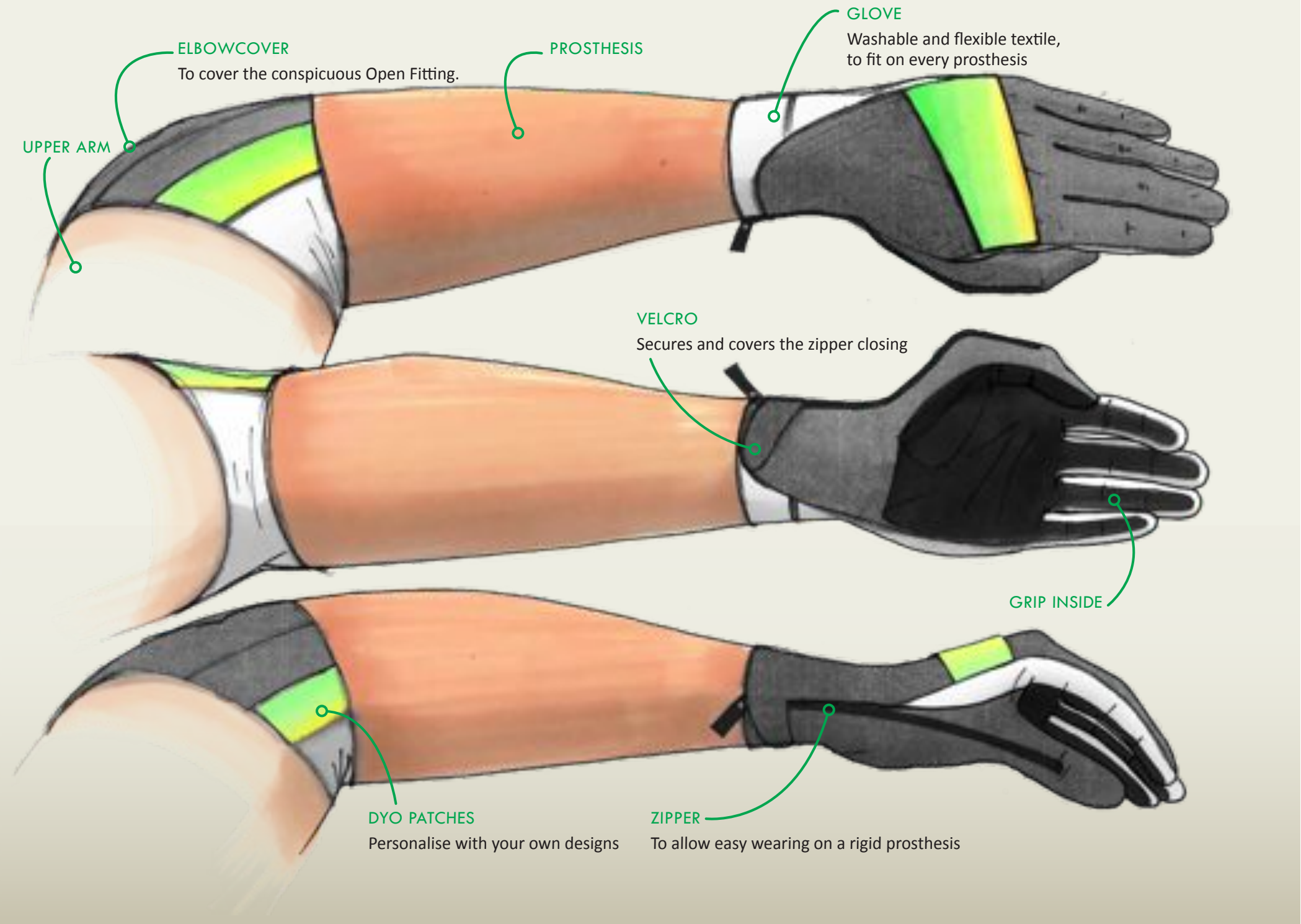

GLOVE
Washable and flexible textile, to fit on every prosthesis
ELBOWCOVER
To cover the conspicuous Open Fitting.
PROSTHESIS
UPPER ARM
VELCRO
Secures and covers the zipper closing
GRIP INSIDE
DYO PATCHES
Personalise with your own designs
ZIPPER
To allow easy wearing on a rigid prosthesis

PRODUCT DESIGN

As concluded in the last chapter, the final product design will be created using the best product features resulting from study 2. The elbowcover of the Integro and the dual glove feature of the Di Guanti will be used to create an improved version of the ArmWear.

The three main functions of the ArmWear allow the teenage prosthesis wearer to quickly add protection and grip to their cosmetic glove, and easily customise the appearance to match their personal style and clothing.

Natural appearance

ArmWear is a line of products that can be worn on any hand-shaped arm prosthesis. Prostheses in general are stiff and difficult to manoeuvre into a small glove. Due to a carefully placed zipper, the ArmWear glove can easily be fitted over the prosthesis. The ArmWear elbowcover is used to conceal a conspicuous fitting that might disturb a natural appearance.

A natural appearance seems to be conflicting with a glove, but the studies have proven the contrary. The shape is the most important issue, and this natural shape is emphasised by tightly fitting the stretch material off the tailor made glove on the prosthesis. The ArmWear shifts the focus to the glove, to create the impression that it is actually worn on a normal hand.

Customisation

The typical look of the ArmWear products can be customised with special DYO patches, which can be designed by the wearer to suit their own personal style. The Velcro fastening makes the patches easily replaceable, to adapt the appearance to that days outfit.

Creating your own designs provides more affection and pride for the prosthesis, and unconsciously increases the acceptation of the prosthesis for the wearer as well as their peers. A prosthesis must be seen as a beneficial addition to the body, an accessory rather than just the replacement of a limb.

Protection

Dependent on the situation, the teenager can decide to wear the ArmWear glove and/or elbowcover. To preserve their vulnerable cosmetic gloves against wear and tear damage, and increase its durability. Despite protection, the ArmWear products will also increase the grip of the prosthesis, to support its natural functionality.

The ArmWear products must give the wearer confidence to do whatever activities he or she wants without having to worry about their prosthesis. Examples of those activities include playing, hobbies, sports, chores and even writing and reading the newspaper are very stain sensitive activities.

Figure 91: Different possibilities of colour schemes for the ArmWear glove and elbowcover, with warm colours, cool colours and greyish tints.

PRODUCT DESIGN
COLOUR

The target group of teenage prosthesis wearers is as diverse as teenagers can be. Boys and girls, sporty and 'geeky', childish and mature, in every possible lifestyle group. The only real characteristic amongst the prosthesis wearers is their prostheses, which makes it difficult to determine a product style that suits everybody perfectly.

Neutral

If the ArmWear would be made one conspicuous colour, there are consequences. Some colours already have strong associations attached to them, like blue (for boys) or pink (for girls). And if you choose such a colour for a very small but diverse target group, you will narrow the target group down to only the people who appreciate that particular colour. Having a neutral colour in combination with the customisable DYO-patches allows for adjust the ArmWear to your personal style and wishes (figure 91).

And there is another drawback of having a glove in an articulated colour. It could match very well with that outfit you wore when you choose the colour, but you wear different clothes every day, in different colours that might not be such a great match. Having a neutral colour in combination with the customisable DYO-patches allows for adjusting the ArmWear to your clothing every day.

Materials

Another thing to take into account is the availability of colours from a certain material. Take for example the neoprene that is used for the grip on the inside of the glove. For small batches, it is virtually only available in anthracite/black (figure 92).

Denim was selected for being a very popular and easily recognisable material amongst the target group, in combination with its known qualities of being strong and wear proof. Denim can be dyed in many colours, but black and blue are the most commonly available. They are easily recognisable as being denim, and associated with clothing (e.g. jeans) (figure 92).

Plain cotton is used for its elastic abilities, widespread availability and again strong associations with clothing (e.g. shirts). This material is available in any colour, but white is chosen since it matches very well with denim (figure 92).

Designers signature

All in all, the white cotton and black denim and neoprene create a very strong contrast in the appearance of the ArmWear, which makes the design very conspicuous (figure 91). If I had not liked this I would have avoided it, but this bombastic appearance with strong contrasts is very typical for my personal design style. It defines me in this product, makes me like it and be enthusiastic about it .

Figure 92: The ArmWear glove and elbowcover next to each other. The numbers correspond to the materials on the facing page.

PRODUCT DESIGN

MATERIAL

These images further visualise the materials that are required for the ArmWear products (figure 92).

1. Stretch denim

The most prominent material is stretch denim, a rough woven cotton. This material is known for its wearproof characteristics in clothing like jeans.

2. Fine woven stretch cotton

Stretch cotton is used in all 'vertical' directions of the glove, to allow a good fitting on the various types of cosmetic prostheses and prosthetic gloves.

3. DYO-Patches

The glove can be personalised to the users personal style. The ArmWear is equipped with Velcro, on which the DYO (Design Your Own) patches can be stuck.

4. Neoprene

The palm of the hand is covered with a soft latex foam, to gain a maximum of additional grip and protection. This material is well known for its grip ability, for example in goalkeeper gloves.

5. Zipper

A zipper mounted from the wrist to the thumb widens the wrist-opening of the glove, to allow easy wearing over a rigid prosthetic hand.

Figure 93: An example of what teenagers would like to do to their Schoolbags. Eastpak has picked up on this trend by organising 'Tag my Bag' events, where professional artists decorate bags.

PRODUCT DESIGN

CUSTOMISATION

Also see appendix E5

As indicated before, one of the main features of the ArmWear products will be their customisability, by means of the DYO-patches (Design Your Own). The user will be able to adapt the product to their own personal taste and style, in order to get more confidence and pride about the product.

There are several ways and techniques that can be used to design the DYO-patches, enlisted here.

Design software

Customisation is a current trend, and many brands offer products that can be designed through an online tool. Through a piece of software the user can select different colours, patterns and materials, and the changes are immediately visible on a 3D model of the product. After purchasing, the product has to be custom build and send to the buyer.

The ArmWear patches can be represented in a 2D view, but nevertheless this method requires investment in software and hardware to offer the right amount of freedom and design aids for every type of users. The users might be very creative and willing to spend days on their design, while on the other hand some users only want to quickly adjust a preset design. All of this needs to be possible with the same software.

For this particular product, it might be better to offer a more tangible solution to the teenagers. Something they can really create themselves at home, without having to wait several days for the delivery.

Iron-on transfer paper

Another possibility is to offer an entirely white DYO-patch. The blank patch comes with a set of iron-on paper, on which the user can print or draw their own designs. A white patch might provoke the natural creativity teenagers possess, like they show when decorating their schoolbags (figure 93).

This might also require the investment in software that offers the right design tools, but now the users can make it themselves. Every sold product offers the same blank patches, which reduces the production complexity.

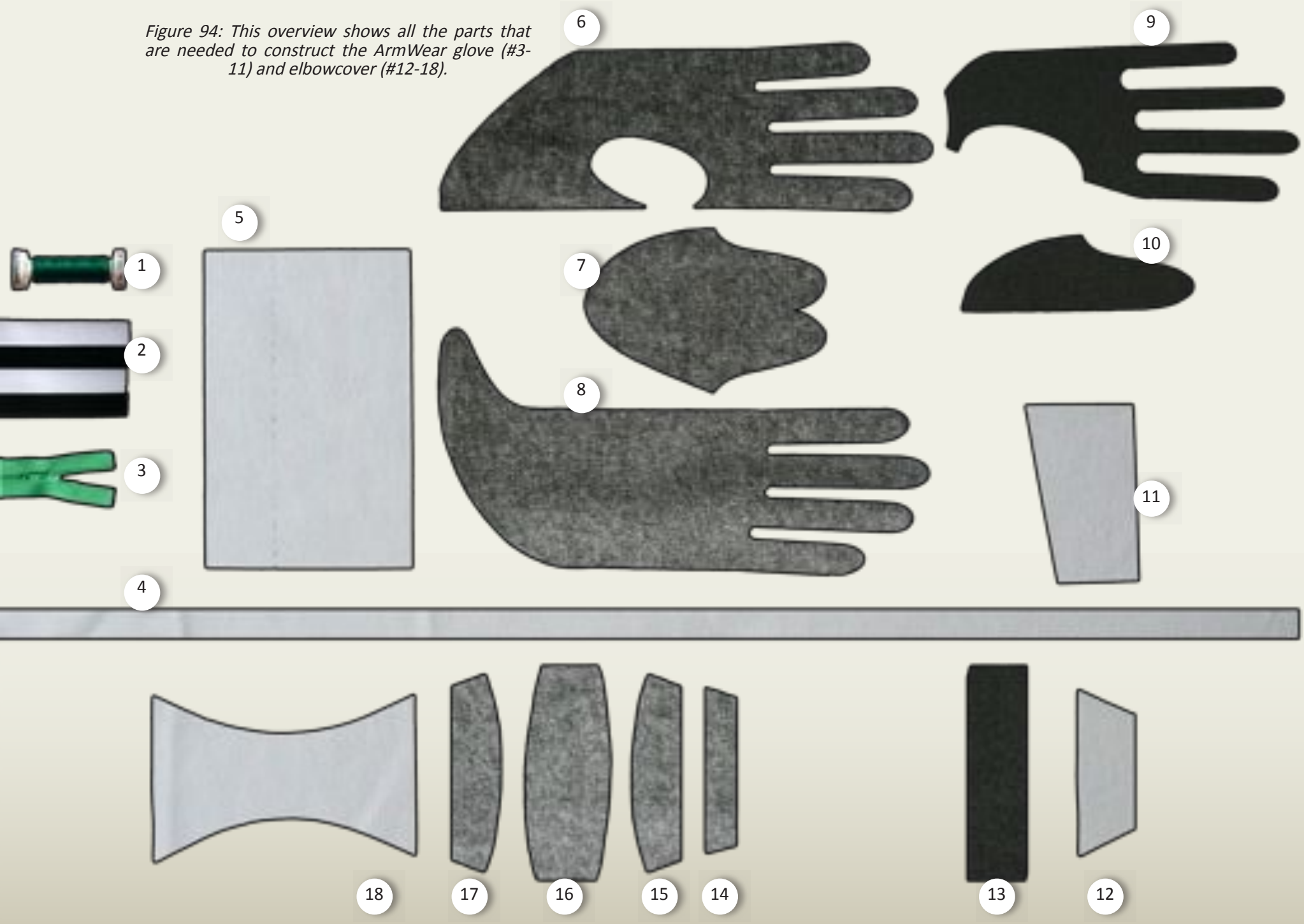
Iron-on adhesive patch

Blank DYO-patches might also be offered with the top covered with a self-adhesive iron-on film. The user can select his own favourite fabric for the top, and iron it on. Several patch designs can be delivered with the product, as an easy solution. No complex lengthy design process, and no stitching required.

Self adhesive Velcro

A more basic solution is the delivery of self-adhesive Velcro strips, which the user can stick to any desired textile to create their own DYO-Patches. This is the cheapest solution, that offers the most freedom, but it also requires the most work from the user.

Figure 94: This overview shows all the parts that are needed to construct the ArmWear glove (#3-11) and elbowcover (#12-18).



PRODUCT DESIGN

PROTOTYPE

Also see appendix H, I

Parts List

This list shows an overview of all the parts of the ArmWear glove and the elbowcover that are required for the production of the ArmWear (figure 94). Detailed sewing patterns can be found in the appendices.

The part numbers are furthermore used in the building instructions in the appendices.

1. Thread
2. Black and white Velcro
3. Zipper: L=18 cm

Glove

4. Cotton spacer: L=90 cm
5. Cotton cuff
6. Denim inside
7. Denim thumb
8. Denim outside
9. Neoprene palm
10. Neoprene thumb
11. DYO glove patch

Elbowcover

12. DYO elbowcover patch
13. Neoprene elbow grasp
14. Denim outside link 1
15. Denim outside link 2
16. Denim outside link 3
17. Denim outside link 4
18. Cotton strap

Building Instructions

A detailed stepwise instruction for building the ArmWear products, as well as images of my building experience can be found in the appendices.

Costs

Aligning the sewing patterns in an ideal way on the selected materials leads to a simple calculation for the material costs for one ArmWear glove, elbowcover and DYO patches.

Neoprene	0,04m²	at 20,05 €/m²	= €0,80
Stretch denim	0,11m²	at 3,57 €/m²	= €0,39
Stretch cotton	0,11m²	at 10,64 €/m²	= €1,17
Zipper 180 mm			= €2,40
Velcro 20 mm	0,64m	at 2,95 €/m	= €1,89
Total material costs			= €6,65

Figure 95: The participant is happily surprised by the looks of the ArmWear glove and elbowcover.

PROTOTYPE

USABILITY TEST

Also see appendix O

Research question

Does the ArmWear perform as desired, regarding its functions and appearance? How are the glove and elbowcover generally appreciated? How is the customisation of the ArmWear with DYO-patches appreciated?

General Setup

The goal of this usability test is to evaluate how the ArmWear products and its features are appreciated by an actual teenage prosthesis wearer. This concise study will contain the fitting of the ArmWear on, performing a few daily tasks and a conclusive interview about the ArmWear and its possibilities.

Before building the prototype, one of the participants in study 2 was asked to participate in a short prototype test session. Since every prototype has to be tailor made for a perfect fitting, only one user test could be done with the prototype.

The Prototype is build to fit Rik, a 21 year old prosthesis wearer who already participated in the PrEmo questionnaire and interview in study 2. Rik is born without his right arm, and learned to live without it. He owns two prostheses. An older cosmetic prosthesis that still fits, and a newer Myo-electric cosmetic prosthesis which he wore during the testing.

The results of the usability test will be structured according to the three ArmWear products: glove, elbowcover and DYO-patches.

Results

Rik is used to his life with only one arm. He performs best with his stump, and therefore does not wear his prosthesis around his friends. All his friends know that he wears a prosthesis, and they are used to it. However he likes to scare them sometimes by shaking hands with his prosthesis.

Rik has a prosthesis for his right arm, and this is generally already noticed when he meets a person and has to shake hands. He shakes hands with his left hand and people act surprised, they don't notice his prosthesis until then.

There are two situation where he really benefits from wearing his prosthesis.

- The natural appearance in public spaces and other important meetings, to not immediately stand out by having only one arm. This issue is more present with good weather, when people generally show more skin. Rik takes his prosthesis into account when picking out his clothing, and therefore does not like to wear T-shirts.
- The only real activity that is easier with a prosthesis is riding a bike, mainly because of the symmetrical pressure on the bar. And on top of that, riding a bike is also an activity in public spaces.

On the question what really should be improved about his prosthesis, Rik replies about the weight of his Myo-electric prosthesis and the easy discolouring of the cosmetic glove, for instance when reading a newspaper...

Figure 96: Close-up of the ArmWear worn over an actual arm prosthesis during the user testing.

Glove

Robust

Rik's first impression about the ArmWear glove is that it looks really robust, mainly because of the denim. Much tougher and more durable than a cosmetic glove (figure 95). Despite the easy discolouring of the cosmetic glove, Rik only gets a new glove when it is damaged, which is once every few months. This used to be much more frequent, when he was little and still played outside a lot. He went through them so fast that the prosthesis maker would always have a spare glove ready for him.

Rik "When I was little, I went through those gloves very fast, haha! More than often my 'hand' was completely ripped open!"

Finger spacing

One thing that has not been taken into account while building the prototype is the spacing between the fingers, which is very minimal with the Myo-electric prosthesis Rik is wearing. Despite the fact that it might be easily solved by bending the fingers a few millimetres apart, it did not prevent the trouble Rik had with pulling on the glove.

Zipper

His parents tried everything to protect his prosthesis, without success. After a while, they even started taping his fingers with band-aids beforehand, and sometimes they used other materials to cover the prosthesis as well. They even considered making his own glove, but they did not know how to sew or how to fit it over his prosthesis. And even if they would succeed, there was no guarantee that it would actually work. The ArmWear would take all of those issues away, by providing an accessible solution.

Despite the zipper, Rik argues that the ArmWear glove might be more difficult to wear over a more realistic silicon cosmetic glove, since those have a sticky and non-slippery surface.

Pair

Nowadays, he does not really need that much protection anymore. Rik got older, and does not play outside that extensively anymore. However, he still deals with the problem of not being able to wear gloves every winter.

Rik would sometimes really like to wear gloves, but this is impossible with his prosthesis. He only gets to wear one glove, making his prosthesis stand out again. In the winter, it would be more natural to be able to wear gloves, and therefore Rik would really love to have a pair of those ArmWear gloves.

Elbowcover

Separate

Rik does not really see the benefits of the ArmWear elbowcover. He does not have an Open Fitting, and therefore does not really feel the need for an elbowcover. He thinks that it would make his fitting only more conspicuous, and he argues that it would be logical to offer those ArmWear products separately, since not everybody needs them.

Writing

Writing while wearing a prosthesis is very difficult, since the paper can not be fixed well with the prosthesis. The paper moves easily, and therefore Rik always takes off his prosthesis when he has to write something. When he tries to demonstrate this, he finds out that it has become much easier to write while wearing the ArmWear elbowcover, since the paper can be firmly fixed.

Rik: "And than the paper just slides uncontrollably... He! The elbowcover works really well here... I can write and the paper doesn't slide! Oke... so maybe I'll take the ArmWear elbowcover as well, haha!"

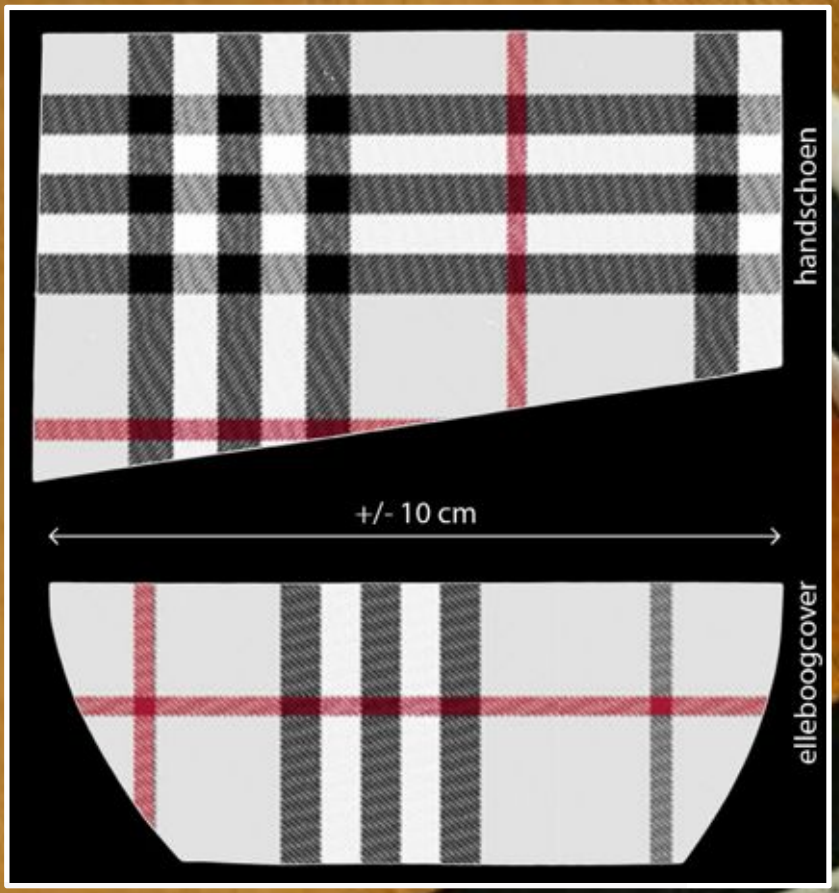


Figure 97: The DYO-Patches designed by the participant as part of the usability test.

DYO-Patches

Design tool

Rik received an empty Photoshop file, to customise his own DYO-patches. But he did not really have a good picture of what he was actually making, and where it would be on the glove and elbow fitting. This really has to be clear in order to make full use of this feature.

He also thinks that graphic design software like Photoshop offers the ultimate freedom, which is both an advantage and a drawback. It might be a bit *too much* freedom for a simple design task like this, especially for people who have no experience in this type of graphical work.

Personal style

Rik eventually edited the colours of a Burberry pattern for the DYO-patches, to really match his personal clothing style (figure 97).

Rik did not consider the possibility of having more of those DYO-patches, so he could alternate. But he really likes the idea. He now made a quite conservative design, but that way the designs can be more outstanding.

General

Practical

Furthermore, Rik thinks that teenagers are the right target group, and maybe younger children could also benefit from this product. They still have a very active life, and don't want to always have to take care of their prosthesis.

Rik: "Its a very practical solution, since you don't immediately ruin your prosthesis at the first bump"

Price

Rik thinks the price of the ArmWear glove must be comparable to other professional gloves. He would be willing to pay around €30 for an ArmWear glove, taken into account that the ArmWear glove is only one glove.

But then again, *if* the ArmWear glove would ensure that children can wear their expensive cosmetic gloves twice as long, insurance companies might also be interested in supporting this solution, and financing would not be an issue anymore.

Conclusion

The ArmWear provides a very good solution for the issues Rik has with his prosthesis and cosmetic glove. He would really like to have two ArmWear gloves, since he has never been able to wear a pair of gloves in the winter before.

If he would have had the ArmWear when he was a bit younger, he would not have consumed so many cosmetic prosthesis while playing outside. He and his parents tried everything to protect his prosthesis by covering it with plaster and glove-parts, but these solutions did not last long and looked rather ridiculous. Rik considers the ArmWear a very good solution for young children.

However, a good fitting is a necessity, and his current prosthesis does not provide enough spacing between the fingers to allow a good fitting.

Figure 98: The discussion with Martijn van der Meeren.

PROTOTYPE

EXPERT INTERVIEW

Martijn van der Meeren, Junior Designer at O'Neill Europe

Also see appendix P

To avoid a subjective evaluation of the ArmWear prototype and the design process, a professional glove designer is asked for his opinion on the matter (figure 98).

Martijn van der Meeren, Junior Designer has several years of glove designing experience at O'Neill Europe. Amongst other things, he created the gloves for the 2010 winter collection.

Process

First of all, the designer is pleasantly surprised by the ArmWear prototype. He considers gloves as one of the most difficult products to design, and to build. One of the difficulties in designing a range of gloves is to fit them in the appropriate price category.

The process of designing a glove starts with research into the current trends and popular products, by visiting expositions and fairs. These trends can be very general, and very specific to the topic of gloves. In many cases, information is bought from specialised trends agencies, regarding materials, colours, patterns and designs for the next collections.

After this Martijn will be sketching, and the actual designing begins. The contour of the inside and the outside of the glove is printed. And on this pile of paper, he starts sketching cutlines. Only when he feels good about these cutlines, he starts applying colours and materials. The final designs are made on the computer with Illustrator, since this allows for easy experimenting with colours and appearances.

Martijn about the prototype: "This is typically something we outsource, we only make flat drawings. But this is cool, really cool!"

His final delivery only contains the inside and outside view of the glove and some specifications about the material, and this is send to the manufacturer in Korea.

With their knowledge, the manufacturer further specifies the materials, and creates a prototype, which is send back to the designer. This is a very time consuming process that can take up to a month.

The designer tests the glove, especially a good fitting is important. Adjustments can be made, and a new prototype will be ordered.

All in all, the process of designing a product line of gloves can take up to 3 or 4 months, before the final design can be produced.

ArmWear

Martijn is really content with the organic cutlines of the glove. They provide the glove with a natural appearance and fitting.

Another very nice feature is the ability customise the blank ArmWear, to really make it your own. He is no expert on prosthetics, so he can not really judge that part of the functionality, but he considers the DYO-patches as one of the strongest features in the design.

Martijn about the DYO-patches: "A small element can determine the appearance of a product, and I think this is a really clever solution. It's a small patch, attachable with Velcro"

Recommendations

Martijn would definitely invest more in the DYO principle, to make it more accessible and tangible.

Also exploring the possibility of a link to other clothing and accessories. For instance by introducing a watch according to the DYO-principles. This watch can be worn on the healthy arm, and completes the image of a fashionable decoration.

Figure 99: Popular brands amongst teenagers. Many of these brands were mentioned by the teenage participants in study 1.

BRANDING

EXPERT INTERVIEW

Tomas van Dam, Global Division Director at O'Neill Europe

Also see appendix Q

Study 2 proved the value of good branding on a product like an arm prosthesis. Teenagers are quite amenable to popular brand names and logos. For further development of the ArmWear, there are two options.

1. Cooperation with a popular brand (figure 99).
2. Introducing ArmWear as a brand of its own.

To get the opinion of an independent expert regarding branding possibilities of the ArmWear concept, an interview was held with Tomas van Dam, Global Division Director at O'Neill Europe. Tomas van Dam is responsible for the development for all products, accessories and footwear for the surf and snow divisions of O'Neill in Europe and Australia. The ultimate question is of course if O'Neill would be professionally interested in this product.

Performance Brands

To answer that 'ultimate question', Tomas thinks that O'Neill is not compatible with the ArmWear project for several reasons. The main reason is that ArmWear does not focus on surf & snow, O'Neill's core target group. The number of actual surfers in The Netherlands is minimal, and the chance that one of them wears a prosthesis is nihil. Prosthesis wearers and surfers are two niche markets with very little common ground.

He suggests to look closer at the target group of prosthesis wearers, to try and find similarities in sports and hobbies, and then find a matching brand with those activities. Since there are no specific descriptors for teenager prosthesis wearers, despite their arm prosthesis, there are two options for branding.

1. Global performance brands like Nike and Adidas, who produce performance gear for the mass sports that are also performed by prosthesis wearers. Their target groups already include prosthesis wearers.
2. The other option would be to look a specialised brands in the fields of prosthetics or gloves. Their expertise and knowledge is closely related to the ArmWear products, which increases the chances for a successful cooperation.

Brand sensitivity

Conclusions about teenagers being sensitive to brands are absolutely agreed on by Tomas. In addition to this, he argues that men are even more sensitive to branding than women. Women focus more on the looks, whereas men are influenced by the safety of a known brand.

Cooperating with popular brands will have the strongest effect in appealingness, since this the popularity of the brand is shared by everybody, or at least by the people that matter to the teenage prosthesis wearers: their teenage peers.

Figure 100: The two phases in the ArmWear marketing strategy.

BRANDING

MARKETING PLAN

The appropriate marketing and sales channels are dependent on the brand and the producing party, resulting in a concise marketing plan (figure).

Phase 1: Core

The target group of teenage prosthesis wearers is a very small and specific core target group. There are no real competitive products in this segment, and therefore a niche-market strategy should be applied, to avoid direct competition with large firms [55].

To start up the production, a suitable partner must be contacted. In this niche market, the sales numbers will be very low, and the production has to be very flexible. There are about 4000 prosthesis wearers in The Netherlands, so it is advisable to also involve the neighbouring countries. Including Germany and France would multiply the core target group by ten, according to the CIA World Factbook. An estimated 25% of these people (=15000) might be interested in buying the ArmWear. They need a new prosthesis every two years, and thus a new ArmWear glove, and the DYO-patches can be sold even more frequently. This optimistic analysis counts for a production number of 7500 ArmWear gloves a year.

Promotion will be done through the revalidation clinics and orthopaedic instrument makers. These locations can be provided with a catalogue or flyers about the ArmWear products, that are handed out to visiting prosthesis wearers. There are several interesting possible branding partners.

- **Delft Prosthetics** is associated with the DIPO. A new company, and the only company in The Netherlands that produces and sells arm prosthetics.
- **Otto Bock** or **Touch Bionics**. Two of the globally leading prosthetics companies when it comes to arm prosthetics. They both recently launched a hand-shaped bionic prosthesis, which can also be perfectly combined with the ArmWear.

Phase 2: Inclusive

In this second phase, the product has already proven its worth for the core target group, and it can be prepared for mass production. Promotion with famous people and trendsetters can evoke a trend, and ArmWear will be sold to retailers of general performance stores (Intersport) and warehouses (H&M) to also approach the mass market.

In order to achieve this, a suitable global partner must be found, ideally with a popular brand image amongst the target group, and the production and promotion facilities.

- **Reusch** or **Pow**. Specialised but globally known glove brands that mainly sell goalkeepers gloves and winter gloves.
- **Nike** or **Adidas**. Global brands who provide performance gear for the mass sports that are also performed by prosthesis wearers. In a way they already include prosthesis wearers in their target group. They often have resources available for charitable projects to strengthen their image.

This is a very optimistic view of the intended future, and in due course the marketing plan must be reviewed and detailed according to the present time.

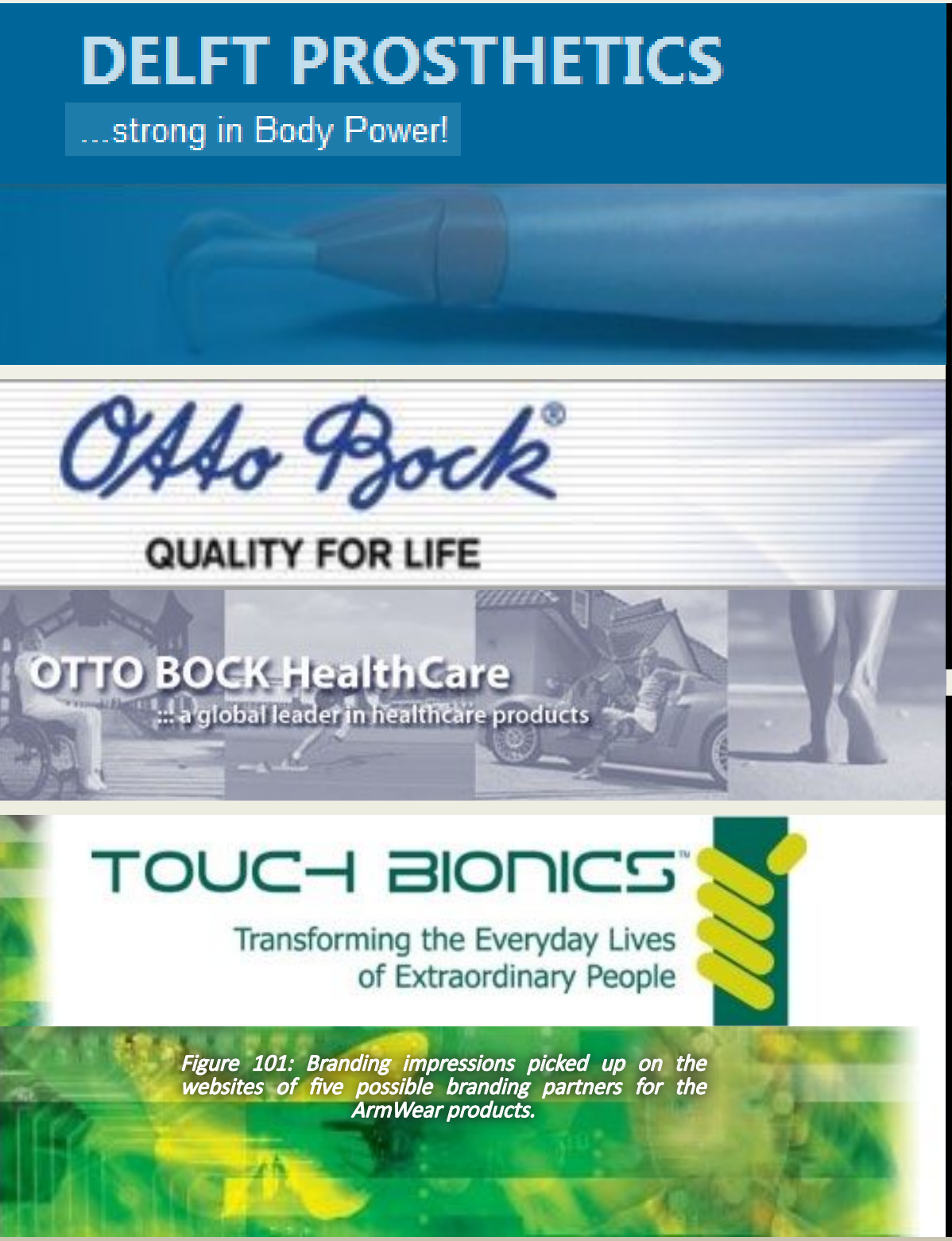


Figure 101: Branding impressions picked up on the websites of five possible branding partners for the ArmWear products.

Webshop

The actual buying of the product is ideally done through the special ArmWear webshop. The website where everybody can customise and order their own ArmWear products. This is suitable for all production numbers.

Many existing brands will already have their own website and webshop, and the ArmWear could easily be added.

Products

- The ArmWear product line will contain three products, and the main product will be the **ArmWear Glove Pack**, that contains the glove and several DYO-patches.
- The elbowcover is especially usefull with an Open Fitting, and since not everybody has such a fitting, it can be ordered separately. The **ArmWear Elbow Pack** contains the elbowcover and several DYO-patches.
- Furthermore, there is the possibility to order additional DYO-patches in the **ArmWear Creative Pack**. This pack contains more DYO-patch designs and creative solutions to customise them.

Production

The ArmWear is an apparel type of product, and it has to be made to measure by a tailor. The buyer gives the measurements of his hand and arm, and the ArmWear can be made. For small production numbers, it is advisable to actually hire a tailor.

For mass production numbers (+500 products), a specialised manufacturer in a low-wage county could be contacted. Many of the larger (glove) brands will already have their connections.

Perceptual Values

It is important for a brand to convey the appropriate perceptual categories when it comes to marketing [50].

ArmWear is a product that approaches arm prosthetics not as limb replacements for the disabled, but as personal accessory to the teenage body. ArmWear is a product that allows prosthesis wearing teenagers to live a carefree active live. Keywords are *active, carefree, personal, creative* and *long wearing*.

On the facing page, website impressions of the possible brands are compared (figure 101). It is obvious that the prosthetic brands try to convey entirely different characteristics than the glove brands.

The prosthetic brands focus more on *medical, health, quality* and *life*. In other words, they focus strongly on healthcare of disabled people. This project showed that congenital arm prosthesis wearers do not feel lesser abled at all. A brand image like this would therefore be absolutely unsuitable for the ArmWear target group.

There are vast differences between the glove brands Pow and Reusch, but it is clear that they both focus *active, authentic* and *performance*. Reusch also adds *professionalism*, whereas Pow is more *rebellion*. Characteristics that stand much closer to the ArmWear values.

This concise analysis includes prosthetic brands since they have a lot of knowledge in their field. But it does show that a the ArmWear products will not immediately match with those brands. In those cases a different branding strategy might be advisable to still achieve the appropriate brand image for the ArmWear products.

Figure 102: A craftsman tailoring in his workshop.

FEASIBILITY

Also see appendix J , K

Costs

Tailor

Questioning several tailors in The Hague resulted in an indicated production price for one glove varying from €12,50 to €50, excluding material. They also indicated that production will get easier and cheaper after several gloves. Also a specialised sewing machinery - suitable for delicate work, like the fingers of a glove - might furthermore decrease the production costs, while increasing the quality (figure 102).

Materials

As calculated earlier in this chapter, the exact material costs will be €6,65 for one ArmWear glove and elbowcover, excluding stitch thread.

Retail price

The participant in the usability test indicated that he would be willing to pay about €35 for one ArmWear glove. Slightly more than half (one glove) of a qualitative pair of gloves, since the ArmWear is a very specialised product that solves a clear problem.

Insurance

One of the main functions of the ArmWear products is to protect the expensive cosmetic gloves from wear and tear damage, replacing these cosmetic gloves can be done less frequently. In other words, insurance companies might also be interested in supporting the ArmWear products, since they could save a lot of money.

Delft Prosthetics

Delft Prosthetics is a newly founded spin-off from the DIPO. They will be focussing on producing several arm prosthetics products that are created by the DIPO. The company is run by volunteers from the TU Delft; people who have other occupational obligations as well, which does not speed the starting-up of a company like this.

In a short interview with Gerwin Smit, cofounder of Delft Prosthetics, he indicated to be interested in the ArmWear products, possibly with production of the ArmWear products as a result. Especially since ArmWear is a very feasible product that solves an existing problem for prosthesis wearers, without the requirement of large investments. It would be an ideal product for a starting company like Delft Prosthetics.

Purchase

What would the ArmWear products change in the process of obtaining a prosthesis? The simple answer is: not much. Children who acquire a prosthesis already visit the revalidation clinic to select the prosthesis they want, and now the ArmWear can be shown as one of the options as well.

This requires cooperation with the revalidation clinics as well, since they have to take the measurements for the hand of the prosthesis wearer. A simple and effective way to do this is to make a flatbed scan of the healthy hand, and order the desired ArmWear products on the ArmWear website.

When the children get older and more independent, they can order their ArmWear products themselves in the same way the revalidation clinic does. Make a scan of their hand, and order the desired ArmWear products on the website.

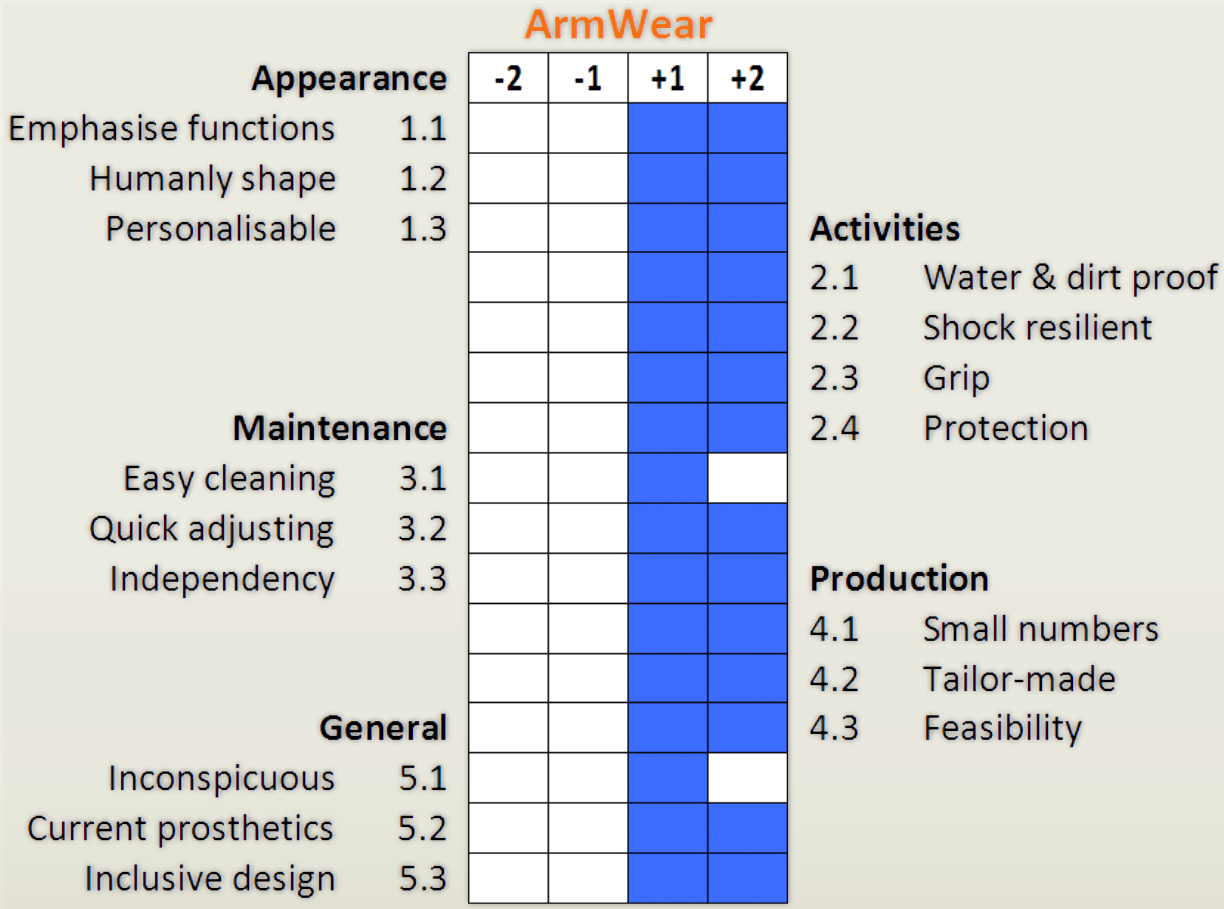


Figure 103: A Harris profile of how well the ArmWear final product design performs

CRITERIA

Harris Profile

The final product design of the ArmWear products seems to be compatible with the vision. But to determine this in a more convincing way, the product will be measured with a Harris Profile according to the criteria formulated in chapter 3. The same criteria to which also the concept designs were rated.

Appearance

1.1 Emphasise arm functions and anatomy

Gloves can be manufactured in different ways, but for the ArmWear glove a technique is chosen which emphasises the shape of the hand and the fingers. The shape of the hand is visible in the denim inside and outside of the glove, and emphasised by the contrast with the white cotton spacer.

1.2 Humanly shape

Both the ArmWear glove and the elbowcover are made of elastic stretch materials, which allow for a tight fitting over any hand-shaped prosthesis. The elbowcover furthermore conceals any prosthesis fitting that otherwise might disturb the natural appearance.

1.3 Fashionable & Personalisable

Customisability is one of the main features of the ArmWear products. The DYO-patches can be customised by the wearer, and easily switched due to the Velcro fastening. With multiple DYO-patches, the user can adjust his prosthesis to match with the outfit of the day.

Activities

2.1 Water & dirt proof

The ArmWear products do not contain any electrical or mechanical parts that might suffer from water or dirt.

2.2 Shock resilient

On top of the wearproof denim, the outside of the elbow is covered with neoprene, to absorb forces from bumping and leaning on this protuberance.

2.3 Grip

Another part that is covered with neoprene is the palm of the hand, which imitates the natural grip function of the fingerprints, to improve grasping and holding with the prosthesis hand.

2.4 Cosmetic glove protection

ArmWear contains a glove and a elbowcover, which the user can wear to quickly adapt to his situation and activity. The strong denim glove and elbowcover provide the necessary protection for active teenage lives, and maintain the natural appearance of the cosmetic glove.

Maintenance

3.1 Easy cleaning

The ArmWear is a textile product, and is easily washable when it is dirty.

3.2 Quick changing/adjusting

The special zipper on the thumb allows for easy fitting over any rigid prosthetic hand, and the elbowcover is quickly put on with Velcro fastening. And even the DYO-patches are very quickly added and switched.

3.3 Independency

Besides the independent and self-evident maintenance of the ArmWear itself, the covered cosmetic glove is also less likely to be damaged. Therefore less maintenance is required, and fewer visits to the orthopaedic instrument maker to replace the cosmetic glove.

Figure 104: The ArmWear ismade to look like an accessory to the clothing of the wearer. Like a fashionable glove.

Production

4.1 Small numbers

The ArmWear products are designed to be tailor made and produced by piece. Costs for materials and production are kept low, even at these small numbers.

4.2 Tailor-made

The ArmWear products have literally become 'tailor-made'. The measurements of the hand and arm of the wearer have to be taken at the revalidation clinic, and the order can be placed at the tailor.

4.3 Feasibility

Feasibility has been taken into account in many stages of the project, with regard to the specific and small target group. In many ways, the prototype has been the first ArmWear production, proving its feasibility.

General

5.1 Inconspicuous

The ArmWear products are made to look like clothing, like an accessory glove (figure 104). In itself the design is not inconspicuous at all, but it does shift the focus away from the prostheses. The ArmWear looks like a normal glove that is worn on a normal hand.
Furthermore, the ArmWear is made to protect the cosmetic glove, to maintain its natural inconspicuous appearance.

5.2 Applicable to current prosthetics

The ArmWear glove can be worn on any hand-shaped prosthesis. From passive and Myo-electric cosmetic hands to the newest range of bionic arms.

5.3 Advantageous: inclusive design

Similar to 5.2, the glove can also be worn on a normal hand. In fact, this is a very realistic option in winter time, when the prosthesis would like to wear a pair of gloves. Marketing-wise, the focus will initially lie on prosthesis wearers. But when the product proofs to be successful, the target group can be expanded to also include normal teenagers.

Overall

These criteria were formulated following the results from study 1, and they expected to cover the most important concerns and requirements about living with a prosthesis.

The ArmWear performs perfectly at every aspect of the criteria: appearance, activities, maintenance, production and general (figure 103). All in all, the ArmWear is a very complete prosthesis enhancement, that provides a feasible solution for several problems with current arm prosthetics and cosmetic gloves. And as the criteria demonstrate, it does so without exceptions.

Figure 105: Easy adjust the appearance of the ArmWear by designing andchanging your DYO-Patches.

CONCLUSION

To conclude this chapter about the final product design, let us glimpse back at the initial aim of the project.

Vision: Design a product usable on current and future arm prosthetics to give teenager prosthesis wearers the opportunity to be confident and proud to wear their prosthesis.

In the previous chapters, several brainstorm sessions were held, many ideas were sketched and three concept designs were formed to meet this design assignment. A second study proved the value of these solutions, and lead to an improved version of the ArmWear concept.

ArmWear

The ArmWear is a fashionable tailor made product, feasible to produce by the piece. The ArmWear products include a glove and elbowcover that can be worn over any existing hand-shaped prosthesis.

Next to the natural appearance, the functions of the ArmWear allow the teenager prosthesis wearer to quickly add protection and grip to their cosmetic glove, and easily customise the appearance to match their personal style and clothing. DYO-patches (Design Your Own) can be custom designed, in order to create a prosthesis they feel confident with and proud to wear.

Natural appearance

ArmWear is a range of products that can be worn on any hand-shaped arm prosthesis. Prostheses in general are stiff and difficult to manoeuvre into a small glove. Due to a carefully placed zipper and natural cutlines, the ArmWear glove can be easily fitted over the prosthesis hand. The ArmWear elbowcover is used to conceal a conspicuous fitting that might disturb the natural appearance.

A natural appearance seems to be conflicting with a glove, but the studies have proven the contrary. The shape is the most important issue, and this natural shape is emphasised by tightly fitting the stretch material off the tailor made glove on the prosthesis. The ArmWear shifts the focus to the glove, to create the impression that it is actually worn on a normal hand.

Customisation

The typical look of the ArmWear products can be customised with special DYO-Patches, which can be designed by the wearer to match their personal style. The Velcro fastening makes the patches easily replaceable, to adapt the appearance to that days outfit (figure 105).

Creating your own designs provides more affection and pride for the prosthesis, and unconsciously increases the acceptation of the prosthesis for the wearer as well as their peers. A prosthesis must be seen as a beneficial addition to the body, an accessory rather than just the replacement of a limb.

Protection

Dependent on the situation, the teenager can decide to wear the ArmWear glove and/or the elbowcover. To preserve their vulnerable cosmetic gloves for wear and tear damage, and increase its durability. Besides protection, the ArmWear products will also increase the grip of the prosthesis, to support its natural functionality.

The ArmWear products must give the wearer confidence to do whatever activities he or she wants without having to worry about their prosthesis. The ArmWear is machine washable, while the cosmetic glove is hard to clean. Examples of those activities include playing, hobbies, sports, chores and even writing and reading the newspaper are very stain sensitive activities.

Concluding: The ArmWear product line is a complete prosthesis enhancement, ready for production. A product based on the concerns of teenager prosthesis wearers, to provide a feasible solution for existing issues with their current prosthetics and cosmetic gloves.

Figure 106: The spacing between the index and middle finger of this functional cosmetic prosthesis is very minimal, it proved to be too little to conveniently pull on the ArmWear glove.

RECOMMENDATIONS

Despite the attempt to deliver a comprehensive report and a perfect product design, there are always some unforeseen improvement possibilities.

Finger spacing

The usability test with the prototype revealed an unforeseen issue with fitting the glove over a prosthesis. The zipper was mounted to allow the entrance of a rigid prosthesis, but the spacing between the fingers was not taken into account. Rik wore a Myo-electric prosthesis that contains a gripping mechanism between the thumb and the index and middle finger. Due to this mechanism, these fingers are extra rigid, and the spacing between the fingers is minimal (figure 106), too little to conveniently wear the glove.

It is likely that this issue is limited to this particular type of prosthesis, but nevertheless a solution must be provided. This issue might be easily obviated by the orthopaedic instrument maker. It seems feasible to bend the fingers an additional few millimetres apart. If this turns out to be impossible, the glove design could be adjusted by joining the index and middle finger.

Sewing techniques

Designing with textiles was investigated extensively for this project. But still I am an industrial designer used to work with solid materials, and apparel design is an entirely different, specialised field of industry.

If the ArmWear products are to be actually produced, which is not unthinkable, it is recommendable to have the sewing patterns and stitching techniques reviewed and maybe even redesigned by an experienced tailor or glove designer.

Product pilot

If the ArmWear products are to actually produced, it is advisable to first perform an extensive pilot test with different participants. One of the possibilities is a usability test lasting several days or weeks, to fully explore and record the potential of the ArmWear products.

DYO-Patches

The O'Neill glove designer already indicated the DYO-patches as one of the strongest features of the ArmWear products. This realisation appeared in a late stage of the project, too late to fully explore the possibilities of the DYO-patches. Therefore it is advisable to address another study to the best ways of having teenagers customise the DYO-patches.

Cosmetic glove replacement

One of the most important problems for functional cosmetic prosthetics is in fact the stiffness of the cosmetic glove. Even the most supple gloves provide a troubling amount of resistance in terms of force, making the prosthesis very energy inefficient. The textile ArmWear glove is extremely supple, and could therefore be very beneficial in this field of prosthetic research.

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Dr. Ir. Dick Plettenburg

DISCUSSION

As in any project, many things could have gone better. The challenge in every project is to recover from those setbacks as best one can.

Expert involvement

One of the things that might be noticed when looking at the index of this report, is the large amount of expert interviews. As it turned out, many people have been approached and involved for their expertise. For feedforward as well as feedback. Due to these expert interviews, many of the qualitative findings could be validated as workable data in this project.

Participants

Participants are always difficult to find and approach, especially in a relatively short project like the 20 weeks of this graduation project. Teenage prosthesis wearers are typically hard to find, since there are only several hundred of these people in The Netherlands. Revalidation clinics were contacted for their patients, and the group of participants was expanded to also include teenage peers and prosthetics professionals. Despite these efforts, the limited number of prosthesis wearers could have influenced the data of the studies in this project.

Study 1 involved 38 participants, but only four prosthesis wearers. Three girls and a boy, respectively in the age of 13, 14, 24 and 21 years, who also all happened to have a similar cosmetic prosthesis. Three of these participants were also willing to do the concern interviews in study 1.

Study 2 involved 32 participants, with 5 new prosthesis wearer, and again an highschool class of teenage peers participated for referencing purposes. Contacting participants went better when the project progressed, and therefore study 2 could be conducted in much less time than the study 1.

PrEmo

The PrEmo tool is used in both studies, and is proven to be a valuable fresh tool that is appreciated by many participants. However there are also some inefficient inconveniences involving the way in which PrEmo is presented. Many of the issues have to deal with the limited freedom and lack of possibilities when setting up the online questionnaire. This might also partly be caused by the fact that I only had access to a student license for this tool.

The amount of emotions resulted in a lengthy process of filling in the questionnaire, something that was not appreciated by every impatient teenager. In the data analysis too, 12 emotions seems quite a lot, since many emotions seem to be related to one another.

Another issues was that the expressed emotions were not always clear to the teenage participants. This could be due to their limited age, experience, empathy or education, but it could also be easily avoided by having and optional explanation available for each character.

The most important inconvenience was the impossibility for additional open or closed questions in the survey. This resulted in difficulties with identifying participants in study 1, but it was solved on time for study 2.

Cosmetic Glove Popularity

One of the most difficult things with performing the PrEmo studies was displaying the prosthesis equally and as they are in real life. The perfect solution would be to have demonstrate each product in real life, but turned out to be impossible within the scope of this project.

The chosen solution focussed more on the appearance of prostheses. It involved equalised images of all prostheses, to also be able to easily include new existing prosthesis designs, like my own concepts.

These images give a good picture of what each prosthesis looks like, but they can never imitate the experience of

encountering a real prosthesis. This might have resulted in less negative emotions for the skin coloured cosmetic prostheses, since the artificialness of these prostheses can only be experienced in real life.

Study 1 vs. Study 2

Study 1 was the first attempt in using the PrEmo tool. Despite a pilot test, the study still suffered some teething troubles, which were solved in study 2.

From the first participant request to the final data analysis, study 1 took nearly two months to complete! Much longer than anticipated, and one of the reasons for the delay in the project. With the experience of study 1, study 2 lasted only a little over two weeks.

Another reduction, besides the running time of the entire PrEmo study, was the number of products that was compared. This was reduced with two products, to 7 in study 2. This was done after complaints, to reduce the duration of filling in the questionnaire.

There were four products that made their appearance in both the studies. The image of the cosmetic glove was changed into a more recent photograph of better quality, nicer looking so to say. It is uncertain how much this has influenced the results. The fact remains that the cosmetic glove was more popular in study 1, when the image of poor quality was used.

A last important change between the studies, which might have its influence on comparing the two studies is the change in participants. As mentioned before, an entire school class participated in both researches, but the children in study 1 were higher educated than study 2. This also shows in the number of questions and complaints from children who did not understand the research.

Design process

Looking back at the design assignment, the design vision and the accompanying criteria, it is striking to see how seamless they match with the final product design. That is of course the desired outcome of any design process, but also consider that I had never designed a piece of clothing before in my life.

Apparel design, more specifically a difficult glove, was something completely new for me. A challenge, which I like. I started the design process with sketching cutlines and surfaces on side views of an blank glove. This seemed logical to me at the time, and the O'Neill glove designer acknowledged this is also his professional approach.

Prototype

Another great challenge was creating the prototype, especially the sewing part. I once saw my mother using a sewing machine, but I never even touched one myself. I'm usually a very quick learner, but to be honest, I had absolutely no clue of what to expect from the outcomes of this challenge. The initial idea was to work together with a fashion designer to guide me through the process, but when she turned out to be unavailable, I was all on my own. As a back-up plan, my mother gave me a very brief sewing instruction, and that was it. All the more reason to be very satisfied with the very decent glove that resulted from a week of sweating over a sewing machine.

Usability Testing

Because of the tailor made nature of the ArmWear products, the prototype was also tailor made for one specific participant, and only one real usability test could be performed. The usability test went prosperous, even though it would have been nice to also test the product with a girl. In the short time of the test, we stumbled upon unforeseen benefits of the ArmWear products. But with just this one test, it is impossible to formulate definite conclusions, especially for a product that is meant to be suitable for every individual in a very diverse target group.

Figure 107: The ArmWear does not only boost the pride and confidence of the prosthesis wearers.

EVALUATION

In November 2009, I attended a lecture from Dr. Ir. Plettenburg about arm prosthetics. I was the only interaction designer amongst many mechanical engineers, typically showing the issue this field of industry deals with: too little attention for the emotional aspect. And the basis for this project was set.

I came up with this project because I wanted to design a personal product with very close relation to the human body, both physical and mental. I think this project has offered me just that. What product could possibly have a closer relationship to the human body than a limb replacement?

I wanted my very last student project to be a meaningful and challenging learning experience, something I can look back to with pride and satisfaction (figure 107). Not just a display of the skills I already gained during my design education, but an opportunity to improve those. A chance to rise to the occasion.

Building the prototype typically displays how I dealt with the challenges during this project. I had never even touched a sewing machine before, not to mention designing a glove. Nevertheless, I ended up sewing one of the most difficult garments imaginable.

Before this project I knew absolutely nothing about prosthetics, and now I feel like one of the few experts with regard to the emotional aspects of arm prosthetics. Next to the skills I displayed and improved, this project taught me a great deal about the resilience of the human body and the importance of personality. And perhaps most importantly, I had fun while doing it.

Figure 71: Teenage insecurity, illustrating the vision.

SUMMARY

INTRODUCTION

In The Netherlands, about 3750 people have an arm prosthesis [51], but the rejection rate is astonishing. 40 to 60% of prosthesis wearers stop using their prosthesis for activities of daily life, vocation and leisure. And 20 to 40% stops using their prosthesis completely [36].

In puberty, appearance and fashion suddenly become of increased importance, for instance when attending a new school [3]. Children can be very honest, direct and even cruel in their opinion and criticism. Insecurity already is an issue for every teen even when there is no reason for it at all, but when you wear a prosthesis the criticism seems credible, and children are easily convinced [32, 40].

Prosthesis professional "I see it often: when children reach puberty, they feel that wearing and using a prosthesis is worse than just missing an arm"

The image and appearance of the prosthesis appears to be of great importance for the acceptation and appreciation of the prosthesis, for the user as well as his social environment [20, 54].

Several sources indicate that prosthetics with a humanly appearance might not be the best solution, or at least not the only possible solution [18, 34, 35, 41, 47].

ANALYSIS

A first study was conducted using the online PrEmo tool [8, 10, 12], amongst prosthesis wearers, their teenage peers and prosthetics professionals, to measure the current emotions and concerns on several existing and futuristic prosthesis designs.

Participants appreciate prostheses that have a natural shape. The cosmetic glove gets very positive emotional responses, and of course there is the super popular Nike sports leg. Comments about this Nike prosthesis show that people appreciate the fact that the prosthesis resembles existing footwear and sports shoes, like it is worn on a healthy leg.

Despite their functionality, hooks in general are very strongly perceived as being frightful and disgusting, by all groups, but mostly by the teenage peers. Associations with pirates and robots are strong, and will also make a wearer an easy target for teasing.

In short, the most important reason to wear a prosthesis is to appear normal and natural. However, in contradiction to the humanly appearance, the interviewees indicated that they would also like their prosthesis to be personal and unique in appearance.

Most prosthesis wearers are perfectly adapted to living with one arm, but they don't like to be stared at. Therefore the most important context to wear a prosthesis is in public places; events where one might encounter 'strangers'. Many sports, hobbies and occupations could be performed without a prosthesis, but also take place in a public environment.

Prosthesis wearer "I once broke the collarbone of my prosthesis arm during soccer. The weeks thereafter I could not use my stump or wear a prosthesis at all, and for the first time in my life I really felt 'dis-armed'."

CONCEPTUALIZATION

The analysis and research of the first two chapters led to the following problem definition.

Teenagers can be very insecure about how they look, and having one arm is a very conspicuous characteristic. Even though they are very well adapted to their situation, others might react surprised or even scared. Wearing a cosmetic prosthesis lowers their feeling of insecurity, even though there are several drawbacks to their prostheses.

Prosthesis wearers only get one prosthesis - for every activity in all situations - while in fact there are situations that require different prostheses with entirely different characteristics. *Sports*, *casual* and *chic* are three important contexts in which people desire a different functionality and appearance from their prosthesis.

Figure 96: Close-up of the ArmWear glove and elbowcover on a prosthesis during the usability test. The participant even designed his own DYO-Patches to match his personal clothing style

CONCEPTUALIZATION

Prosthesis wearers too want to belong to a group, but not stand out in the crowd. They want to be unique in the way they like, and not simply because of their amputation. They see their prosthesis not as a replacement of the arm, but as an accessory to the body. A means to express themselves.

Cosmetic gloves are vulnerable, maintenance sensitive and expensive. This makes them unsuitable for physical activities that teenagers might want to perform during their occupation, sports, hobbies and daily chores.

Vision (figure 71): Design a product usable on current and future arm prosthetics to give teenager prosthesis wearers the opportunity to be confident and proud to wear their prosthesis.

ASSESSMENT

The idea generation resulted in 3 concepts suitable for a second PrEmo study. The features of Integro, ArmWear and Di Guanti each focussed on a different improvement of current prosthetics. Premo study 2 showed that these concepts were highly appreciated, especially by the prosthesis wearers themselves.

There seems to be a dichotomy in participants: a conservative group in favour of skin coloured prostheses, while another group appreciates a conspicuous customisable alternative. However, two important issues for this customisation are time and approachability.

Brand can make a huge difference in the appreciation of a product. A popular brand will have certain values attached to it, which will reflect good on the prosthesis. In this study, everybody choose the 'Puma' prosthesis over the similar but unbranded version.

The Open Fitting improves the wearing comfort for the prosthesis wearer, but it also affects the natural appearance of the prosthesis. The Integro elbowcover offers the possibility to cover the Open Fitting, and gets very positive comments for this feature.

The final product design is created by improving the ArmWear concept with the best product features resulting from study 2.

ArmWear

The ArmWear is a fashionable tailor made product, feasible to produce by the piece. The ArmWear products include a glove and elbowcover that can be worn over any hand-shaped prosthesis, and DYO-Patches (Design Your Own) to customise your own ArmWear (figure 96).

Due to a carefully placed zipper and natural cutlines, the ArmWear glove can be easily fitted over any prosthesis hand. The ArmWear elbowcover is used to conceal a conspicuous fitting that might disturb the natural appearance. The ArmWear shifts the focus to the glove, to create the impression that it is actually worn on a normal hand.

The ArmWear glove and elbowcover can be customised with a DYO-Patch, which can be designed by the wearer to match the appearance of his outfit. Creating your own design provides more affection and pride for the prosthesis. A prosthesis must be seen as a beneficial accessory rather than just the replacement of a limb.

Dependent on the situation, the teenager can decide to wear the ArmWear glove and/or the elbowcover. To preserve their vulnerable cosmetic gloves for wear and tear damage, and increase its durability. Besides protection, the ArmWear products will also increase the grip of the prosthesis, to support its natural functionality.

The ArmWear products must give the wearer confidence to do whatever activities he or she wants without having to worry about their prosthesis. The ArmWear is machine washable, while the cosmetic glove is hard to clean. Examples of those activities include playing outside, hobbies, sports, chores. Even writing and reading the newspaper are very stain sensitive activities.

Concluding: The ArmWear product line is a complete prosthesis enhancement, ready for production. A product based on the concerns of teenager prosthesis wearers, to provide a feasible solution for existing issues with their current prosthetics and cosmetic gloves.

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Several images were used in this report. Many of the image sources will be referring to the literature list. All sources are sorted by figure numbers, in some cases more sources were used to for one composed image.

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Figure 105: Prostheses are a much more personal and emotionally charged product than ever anticipated and designed for.

PRODUCT EMOTION

Prosthetics are a much more personal and emotional product than ever anticipated, while this emotional side has never truly been attended (figure 105).

Products can evoke feelings that are good or bad, and designers naturally strive for products that evoke good feelings, since they have all kinds of favourable effects; they are bought, talked about in a positive way, contribute to brand image and are even forgiven some design imperfections. On the other hand, products that evoke bad feelings generate disappointed users and complaints, and this still applies too often to prostheses. These feelings are an important part of emotions, and so is behaviour. Occurrence of an emotion tends to result into a specific behaviour. For instance, angry people shout and fight while sad people fall silent and withdraw [13].

In other words; products evoke feelings and emotions that can affect unconscious behaviour. It would be very useful if we can apply this theory to the field of prosthetics, where people generally have negative feelings associated with prostheses. An emotion-driven redesign for an arm prosthesis for adolescents seems appropriate and even logical.

Product experience

To know exactly where product emotions stand in the interaction with products, it is important to know on which levels people can interact with products. Desmet and Hekkert argue that there are three basic levels of product interaction; instrumental interaction, non-instrumental interaction and non-physical interaction. Instrumental and non-instrumental interaction have to deal with physical alteration of the product, functional or not, whereas non-physical interaction has to do with mere feelings towards a product, like fantasising, remembering and anticipating. All these actions and processes involved will add to the experience one has with a product, and the experience is always influenced by its context [11].

Three types of product experience are distinguished in the user-product relation; aesthetics experience, experience of meaning and emotional experience.

- The aesthetic experience is the capacity of a product to delight one or more of our sensory modalities, whether this is sight, sound, touch or another sense of a product.
- The experience of meaning deals with cognitive processes, like interpretation, memory and personal association. We can for instance address metaphors and personality to a product.
- The emotional experience deals with our basic human emotions towards a product, like love and disgust, fear and desire, pride and despair [11].

In this description, it is arguable that every experience can rise to an emotional experience, even those of aesthetics and meaning. Therefore emotions can be seen as the basis to measure product experience, as it is acknowledged by emotion designer Desmet [45]. Emotions must not be ignored, and somehow this is exactly what has always happened with the development of arm prostheses.

Desmet: "Ignoring the emotional side of product experience would be like denying that these products are designed, bought, and used by humans."

Figure 107: Desmet distinguishes three groups of appraisals; usefulness, pleasantness and rightfulness. Each appraisal can manifest in many variations.

Product emotions

Emotional design is a tough field for several reasons. First of all, product emotion is a very broad and complicated concept, especially since products tend to evoke different conflicting emotions. And there is the problem of emotions being subjective, not only differing for every individual, but also dependent on external influences like time [26].

Desmet describes the function of emotions in regard to products that we use. Emotions are an acute response towards a situation, a so called appraisal, to motivate us in making decisions (figure 106). In this perspective, pleasant emotions pull us *toward* a product, whereas unpleasant emotions will push us *away* from that product [9 , 13, 45]. This theory shows how negative peer responses towards a prosthesis can result into the abandonment of the product.

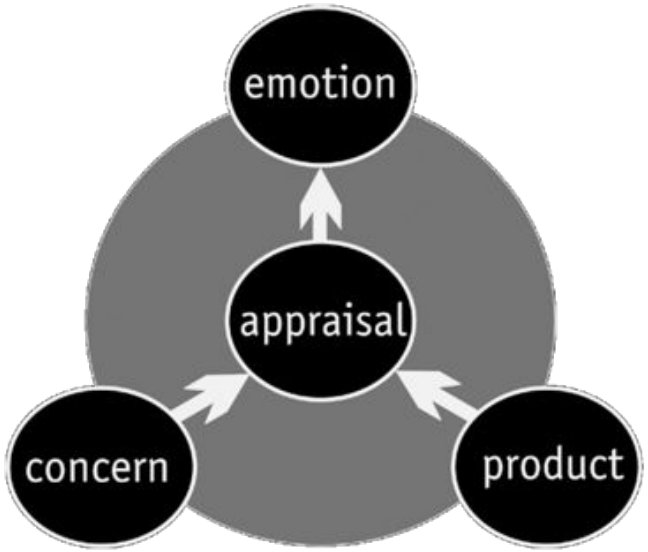


Figure 106: The basic model of product emotions shows that the combination of object and concern elicits an appraisal, which evokes an emotion.

Research into classifying these individual appraisals has lead to a division of appraisals in three levels, regarding usefulness, pleasantness and rightfulness. A situation can elicit a good feeling because it is useful, pleasurable or rightful. And the other way around, bad feelings may arise because it is harmful, painful or wrongful. However, these appraisals can manifest in many different valuations (figure 107) [13].

- Usefulness is related to the things that we want; our personal goals. Achieving (parts of) those goals is appraised useful, and our behaviour will be adapted correspondingly. For example, prosthesis wearers will have certain personal goals (e.g. fitting in), and when the prosthesis is disadvantageous in achieving this goal (e.g. teasing), the wearer will experience a negative appraisal possibly resulting in prosthesis rejection.
- Pleasantness is related to the things that we enjoy; our personal likes and dislikes. These are stimulations that are appraised as pleasurable in itself. For example, the appearance of a sophisticated prosthesis design might elicit this appraisal, just like personalising it with your favourite colour or a likable print. And also the uncanny valley theory is an example of an unconscious unpleasantness.
- Rightfulness is related to the things that we should; our believes and moral standards. Stimuli that exceed our standards and expectations are appraised as rightful. For example, the impression is often created that technology is very advanced and artificial arms and legs are as good as the original limbs, but when these expectations are not met, the wearer will evidently experience wrongfulness.

Figure 51: PrEmo consists of 12 animations of a character, to represent 6 positive and 6 negative emotions. Participants are asked to identify their own mixed feelings with the expressions of this character, to assess to what amount each of the emotions is elicited by the appearance of a product.

For each type of appraisal, products can generate at least three different emotional attachments, with a product-focus, an action-focus and a self-focus [13].

- A product can have a very direct emotional impact as such. The results of seeing, touching, tasting, hearing and feeling might elicit emotions, and can all be directly attributed to the product characteristics. This context of experience includes not only the actual perception of a product, but also the our goals and expectations.
- Products are used to enable and facilitate all kinds of activities. These activities themselves can be useful, pleasurable or rightful. In this case, the emotion is focussed on the action, and not the product.
- Owning and using a product also have their influence on the identity of the user. Products can affect how the user is perceived by others, but also have their affect on the self-image. Appraisals come into being because people are emotional about who they are and how others perceive them.

Combining the three appraisals with the three levels of human-product relationships leads to a matrix of nine sources of product emotions. This matrix does not necessarily define all the possible sources of product emotions, but it explains why, how and when emotions are evoked, and how products can elicit mixed emotions [45].

PrEmo

Several methods have been developed and explored to make emotional design more tangible and provable [8, 10, 12]. They all deal with having the target group quantify their emotions and qualify their appraisals towards existing or new products. The findings were used to develop a tool that allows participants to describe their emotions towards a product in an unambiguous and unconscious way; 'PrEmo', short for Product Emotion Measurement instrument.

PrEmo has been developed as a nonverbal self-report instrument, to measure specifically emotions evoked by product designs. Instead of using words, respondents can report their emotions with the use of expressive animations. Six pleasant and six unpleasant emotions are measured that are often elicited by product design (figure 51). PrEmo is a computerised tool that can be used in online questionnaires. [10, 48].

In practice, products can be compared for instance by using images. Then for each product, the participant is asked to indicate how well each of the emotion animations fits to his feelings. For each research, a maximum of 8 products or stimuli can be compared.

Several project have already shown the value of this new tool in product emotions [10, 12], but the fact that it is now being commercially exploited speaks volumes [48].

TOTAL	Avg Positive	Desire	Satis-faction	Pride	Hope	Joy	Fasci-nation	Avg Negative	Disgust	Dassatis-faction	Shame	Fear	Sadness	Boredom
Cosmetic glove	1,46	1,4	1,7	1,2	0,9	1,7	2,0	0,80	0,8	1,0	0,7	1,0	0,6	0,8
Becker red hand	0,90	0,6	1,2	0,8	0,5	1,1	1,3	1,25	1,9	1,6	0,9	1,6	0,8	0,9
Huseklepp's Immaculate	1,33	0,9	1,5	1,2	0,9	1,7	1,8	0,98	1,1	1,3	1,0	1,1	0,7	0,8
Split-hook	0,60	0,3	0,7	0,7	0,4	0,5	1,0	1,63	2,3	1,9	1,1	2,2	1,0	1,2
Lesa hook	0,68	0,4	0,8	0,7	0,5	0,8	1,0	1,54	2,1	1,8	1,2	2,0	1,1	1,1
Wilmer Appealing Prehensor	0,65	0,4	0,8	0,6	0,4	0,7	1,1	1,58	2,4	1,7	1,1	2,0	1,1	1,2
Ossur Cheetah leg	1,15	0,9	1,2	1,3	0,8	1,1	1,8	1,16	1,6	1,5	0,8	1,6	0,7	0,8
Eames wooden leg	0,80	0,5	1,0	0,7	0,5	0,9	1,2	1,52	2,0	1,7	1,0	1,9	1,2	1,4
Nike sports leg	2,62	2,3	3,0	2,6	1,8	3,1	2,9	0,28	0,3	0,3	0,3	0,4	0,2	0,3

Figure 108: Detailed research data from study 1, containing the average results for all emotions for all participant groups.

WEARERS	Avg Positive	Desire	Satis-faction	Pride	Hope	Joy	Fasci-nation	Avg Negative	Disgust	Dassatis-faction	Shame	Fear	Sadness	Boredom
Cosmetic glove	1,83	2,0	2,0	1,3	1,5	2,0	2,3	0,17	0,3	0,0	0,0	0,3	0,0	0,5
Becker red hand	0,21	0,0	0,5	0,0	0,3	0,3	0,3	2,04	3,5	2,3	0,8	1,8	1,5	2,5
Huseklepp's Immaculate	0,88	0,8	0,8	0,8	0,5	1,0	1,5	1,29	2,0	1,8	0,5	1,5	0,8	1,3
Split-hook	1,00	0,3	1,5	0,8	0,8	1,5	1,3	0,83	1,8	0,5	0,5	0,8	0,8	0,8
Lesa hook	0,58	0,8	0,5	0,5	0,8	0,3	0,8	1,58	2,5	2,0	0,5	2,0	1,5	1,0
Wilmer Appealing Prehensor	0,75	0,0	0,8	0,8	0,3	1,3	1,5	1,58	2,0	1,5	1,0	1,5	1,8	1,8
Ossur Cheetah leg	0,88	0,8	1,3	1,3	0,3	0,5	1,3	1,08	1,8	2,0	0,5	1,0	0,5	0,8
Eames wooden leg	0,54	0,3	0,8	0,3	0,5	0,3	1,3	1,75	2,5	2,5	0,3	1,8	1,3	2,3
Nike sports leg	2,21	2,3	2,5	2,0	1,3	2,8	2,5	0,33	0,3	0,3	0,8	0,3	0,0	0,5

PROFESSIONALS	Avg Positive	Desire	Satis-faction	Pride	Hope	Joy	Fasci-nation	Avg Negative	Disgust	Dassatis-faction	Shame	Fear	Sadness	Boredom
Cosmetic glove	1,04	1,5	1,3	0,8	0,5	0,8	1,5	0,42	0,3	1,5	0,0	0,3	0,3	0,3
Becker red hand	0,79	0,5	1,0	0,3	0,5	1,3	1,3	0,75	1,8	1,0	0,0	1,3	0,5	0,0
Huseklepp's Immaculate	0,58	0,3	0,3	0,3	0,8	1,0	1,0	1,04	1,8	1,5	0,8	1,3	1,0	0,0
Split-hook	0,38	0,3	0,5	0,5	0,5	0,0	0,5	0,92	1,3	1,3	0,3	1,8	0,8	0,3
Lesa hook	0,71	0,3	0,5	0,8	0,5	1,0	1,3	1,17	1,5	2,0	0,5	2,3	0,5	0,3
Wilmer Appealing Prehensor	1,21	0,8	2,0	0,8	0,8	1,3	1,8	0,42	1,0	0,3	0,0	1,0	0,0	0,3
Ossur Cheetah leg	0,54	0,5	0,3	0,5	1,0	0,5	0,5	0,92	1,8	2,0	0,3	1,3	0,0	0,3
Eames wooden leg	0,58	0,3	0,8	0,5	0,3	0,8	1,0	0,63	1,0	0,8	0,0	1,3	0,0	0,8
Nike sports leg	2,25	1,8	3,3	2,3	1,0	2,8	2,5	0,04	0,0	0,3	0,0	0,0	0,0	0,0

PEERS	Avg Positive	Desire	Satis-faction	Pride	Hope	Joy	Fasci-nation	Avg Negative	Disgust	Dassatis-faction	Shame	Fear	Sadness	Boredom
Cosmetic glove	1,50	1,4	1,7	1,4	0,9	1,7	2,0	0,92	0,9	1,0	0,9	1,1	0,7	1,0
Becker red hand	0,98	0,7	1,3	1,0	0,6	1,0	1,3	1,26	1,7	1,6	1,0	1,6	0,8	0,8
Huseklepp's Immaculate	1,51	1,0	1,9	1,4	0,9	1,8	1,9	0,97	0,9	1,2	1,1	0,9	0,7	0,9
Split-hook	0,61	0,4	0,7	0,8	0,3	0,4	1,1	1,84	2,5	2,1	1,4	2,5	1,1	1,5
Lesa hook	0,71	0,4	0,9	0,7	0,5	0,8	1,0	1,62	2,1	1,8	1,5	1,9	1,2	1,2
Wilmer Appealing Prehensor	0,58	0,4	0,7	0,6	0,4	0,5	0,8	1,75	2,6	1,8	1,3	2,2	1,2	1,3
Ossur Cheetah leg	1,27	0,9	1,2	1,4	0,8	1,2	2,0	1,24	1,6	1,4	1,0	1,7	0,9	1,0
Eames wooden leg	0,89	0,6	1,1	0,8	0,6	1,0	1,3	1,61	2,0	1,6	1,3	1,9	1,4	1,3
Nike sports leg	2,77	2,4	3,1	2,8	2,1	3,2	3,0	0,32	0,3	0,3	0,3	0,4	0,3	0,3

APPENDIX B

STUDY 1: DETAILED DATA

These graphs show an overview of the average values for all the emotions measured in the PrEmo research (figure 108). The six positive emotions and one overall value are accentuated in green, and the six negative emotions and an overall value are red.

The top figure shows the values for the total number of participants, while the other images give an overview of just one of the participant groups.

Within the figures, the extreme values are also accentuated. Green for a the most positive prosthesis, and red for the most negative result.

The 9 prostheses are sorted in the three prosthesis groups: 3 hand-shaped, 3 hook-shaped and 3 leg prostheses.

The data was collected from the input of 38 participants: 4 prosthesis wearers, 5 prosthetics professionals and 29 teenage peers.

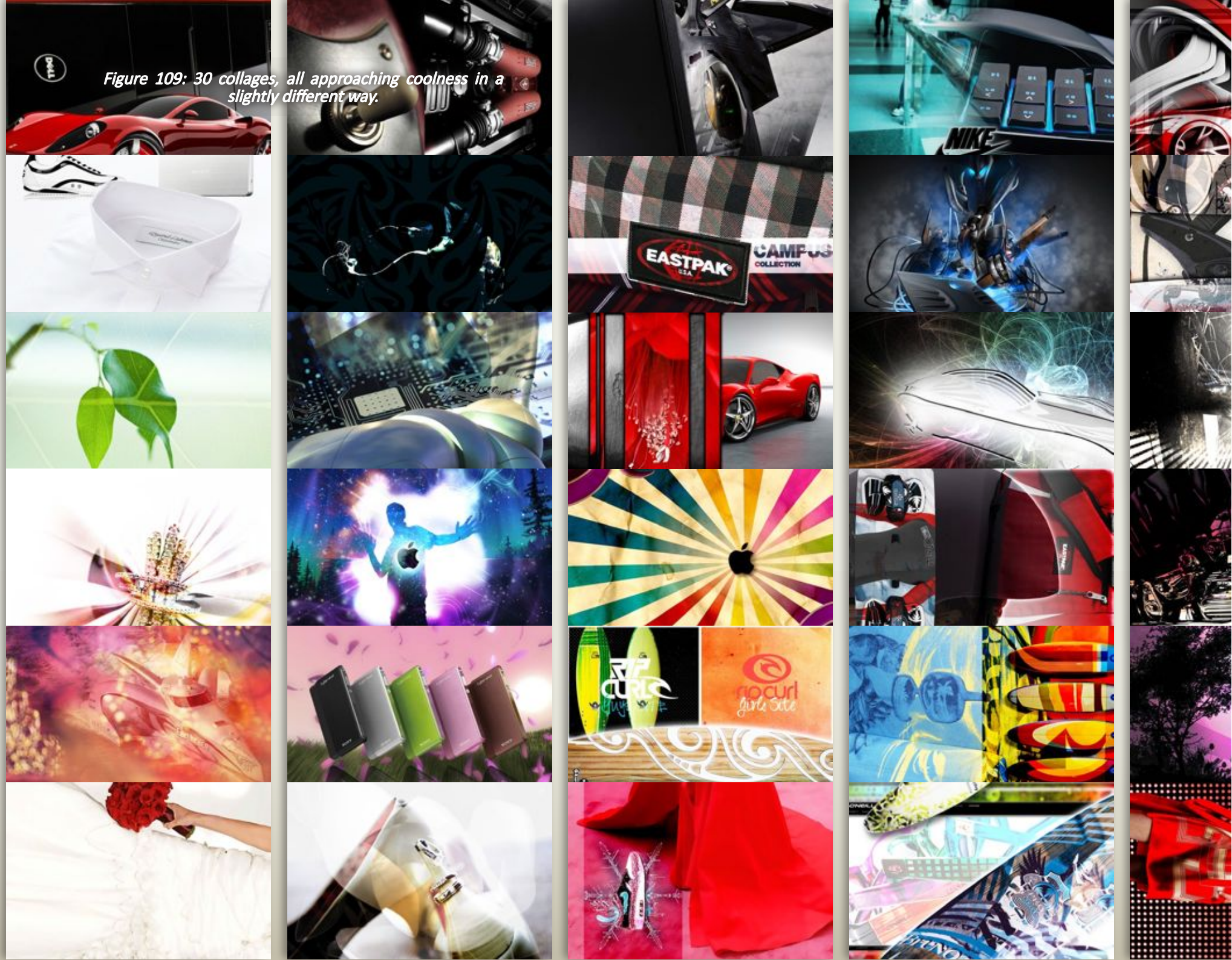


Figure 109: 30 collages, all approaching coolness in a slightly different way.

APPENDIX C

COLLAGES: TEENAGER COOLNESS

Cool Appearance

In order to capture 'coolness' in a more tangible way, several collages were made (figure 109). Each expressing coolness in different ways: with different styles, brands, objects, shapes and colours. In total, 30 digital collages were made with Adobe Photoshop CS4, and printed on handy A5 size paper.

Because of the amount and versatility of the collages, they can be arranged and sorted in different ways (figure 111). These collages and arrangements will be used during the interviews to evaluate what kind of coolness teenagers want, and why they like some collages over others.

Participant responses

During the interviews, these collages were presented to the participants, in order for them to select a few favourites (figure 110).

Figure 110: Favourite collages from the participants.

Figure 111: The collages can be arranged and sorted in different ways.

Conclusion

The participants all indicated they liked the quality of the collages, but that was about it for the similarity. They all choose different collages with the same reasons, or similar collages for different reasons. Some people are more focussed on abstract colours, while others look more for recognizable shapes and objects.

Individuals have a unique combination of individual characteristics and personality [41]. And in combination with a unique context, this results in a unique personal style.

All in all, the choices were almost as diverse as the number of collages, which can only result in the conclusion that taste is very personal. This leads to the discrepancy between '*making a product personal*' and '*having a large target group*' [41].

The more distinct a style is, the less people will like it. But the people who do like it, will like it even more. Conspicuous colours, patterns and contrasts play an important role, as well as recognizable objects and brands that represent certain values.

strijkplaatjes.

OMA's

jongens vs. meisjes.

maten.

patronen.

LEER

STOER

bewerken.

één keer vs. vaak

kraaltjes

toegankelijk.

gaten.

geheim

zelfdoen.

Bewerkingen

persoonlijk

Maken prothese

- veters

- details op neutraal.

sieraden

tattoeage

smaak

ontwikkelen.

tekenen verf.

stiften.

zelfdoen.

kleuren

basisdelen.

'stijlitem'

inzetten

reepje stof.

↳ bij kleding.

samenwerking.

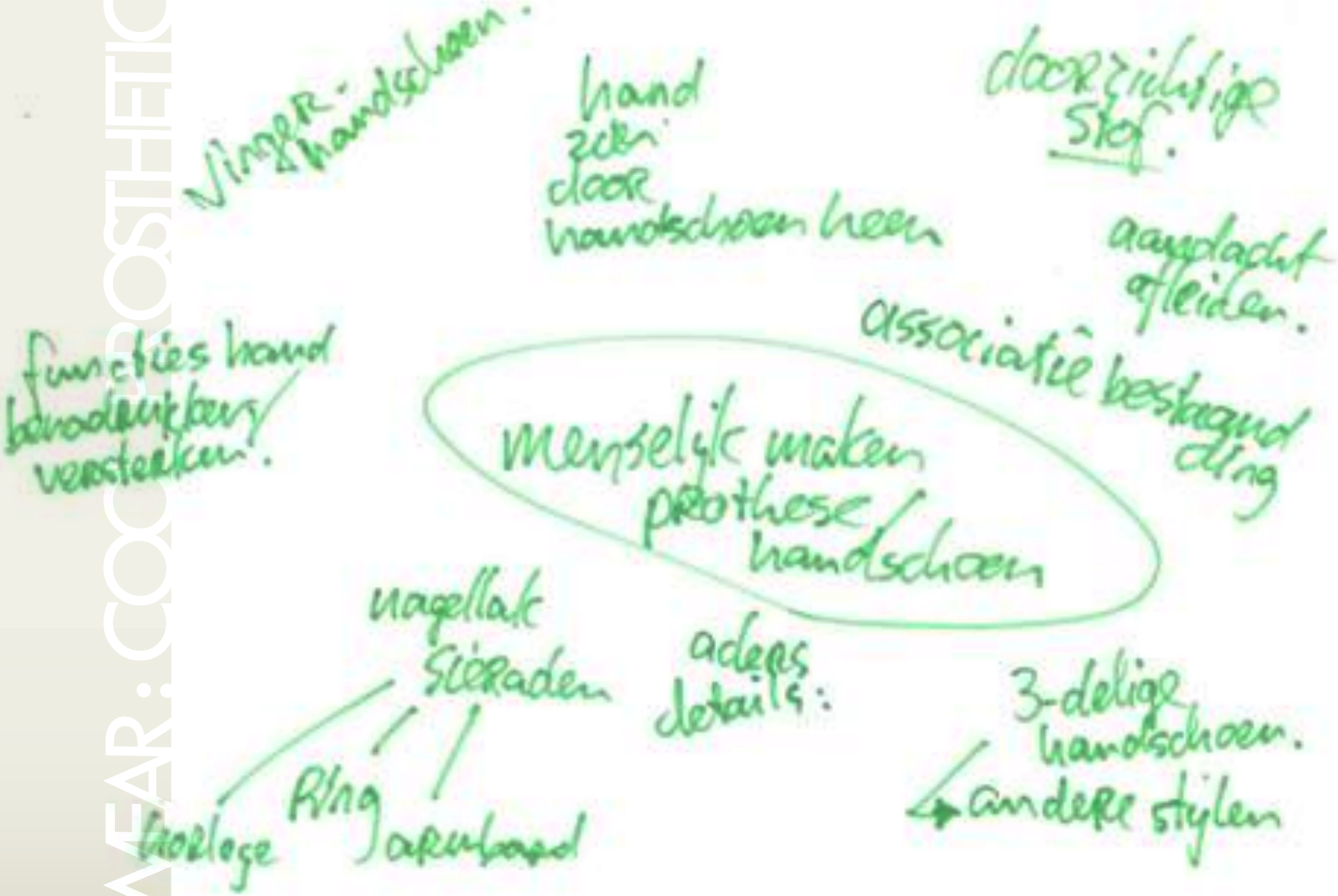
APPENDIX D

BRAINSTORM SESSIONS

Three brainstorm sessions were done together with fashion designer Jacintha van der Brink. They dealt with the following topics:

1. *How to create a personal prosthesis?*
2. *What functions are important?*
3. *How to make a prosthesis humanly?*

Functies
Veranderen
↳ situaties.
tijd
5 vingers
'stijlitem'
nuances
ZOMER
waternevel
waaier
dunnere stof
WINTER
andere hand
ook handschoen.
collectie
magneet
veter
elastiek
knopen (druk)
rits
klittenband
laagjes
haakjes
schoonmaken
flexibel.
bescherming.
zakje
opbergen.
grip
vashouden
dunnen


vinger-handschoen.
hand zien door handschoen heen
doorzichtige stof.
aandacht afleiden.
associatie bestaand ding
functies hand benadrukken/ versterken.
menselijk maken prothese/ handschoen
nagellak
sieraden
horloge
Ring
armband
adeps details:
3-delige handschoen.
andere stylen

695

5

APPENDIX E

INSPIRATIONAL COLLAGES

E1: Teenager Clothing

The target group in this project is teenagers in the age of 12 to 20 years with a transradial arm amputation. This group consists of only several hundred people (estimated) in The Netherlands. Except for their arm amputation, these children are normal teenagers in every way, including their style and fashion-consciousness.

Teenager lifestyles can be quite extreme and divergent. Gothic, alto, skater and hip-hop are several examples of well known clothing styles. Nevertheless, the majority of the people has a more moderate 'pop' fashion style, with influences from the hip-hop scene due to the popularity of music channels TMF and MTV.

Clothing in this pop style can be found at large warehouses like H&M, C&A and Intersport.

Style

- Denim is still unabated popular. Dyed, baggy, skinny or with a wear and tear look.
- Plain coloured tops with or without a conspicuous print. Colours for this summer are 'soft' but fresh, in combination with spotless white.
- Layers are always good. Hoodies. Scarfs. One shirt over another.
- Accessories can very well be decorated with prints of tartan and checker patterns.

Hey Dave -
Have you seen these great new Elite Touchy gloves? Perfect for texting when you're on the slopes!

www.allfunent.com

E2: Existing Gloves

Gloves exist in many variations. Different function and purpose result in different shapes, materials, colours and textures, and eventually entirely different appearances. The products will also be associated with the context of its function. A cycling glove will look great on a cyclist, but not so much with a suit.

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DFI Medisign, Sept.2010
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DIPO
Delft Institute of Prosthetics and Orthotics
Dr. Ir. Dick Plettenburg

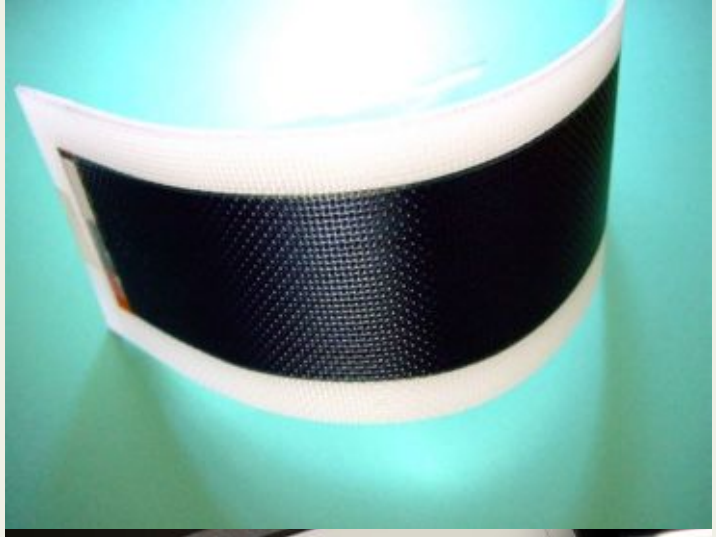
E3: Existing Sleeves

Gloves are well known accessory covers for the hand. But arms are less frequently covered with accessory products. There are of course watches and bracelets, and sleeves are commonly attached to clothes like sweaters and shirts, but additional arm covers are quite rare.

Most of the additional sleeves have a very clear function, and are not worn in daily life. They might be worn as physical protection during sports (basketball, baseball) or occupation (animal doctor). Other sleeves protect against UV radiation, chemicals or contamination.

Figure 112: A sleeve with a very clear function.

An interesting exception is the 'tattoo sleeve'. This sleeve is actually attached to a shirt, but it appears to be an arm covered in tattoos. This way the wearer can have the experience of being heavily tattooed, without all the drawbacks.



Introduction

E4: Apparel Technology

Various attempts have been made to mix clothing and technology, resulting in experimental techniques and materials.

An important challenge with mixing fabric and electronics is that fabric is flexible, elastic, mobile and has several other wearable characteristics. Whereas electronics is generally fragile, expensive, sturdy and most importantly electricity is required. Recent developments have lead to fabrics that are capable of emitting light and buttons and other flexible electronic parts that can be woven into fabrics.

A trend in electronics is the constant urge to reduce size, weight and power consumption, while boosting the functions. This has lead to flexible displays with a very low energy consumption.

Other developments show the increased importance of wireless data transferring, and the accompanied technological developments in this field.

Another trend is the search for green solutions, especially regarding energy generation and consumption. More and more advanced solar cells are one outcome of this trend, as well as power generated by the body, by means of motion and heat.

Nike and iPod already explored the functionality of these technological developments with an interesting experimental product called *Nike+iPod Sport Kit*. This is in fact a very small pedometer that can be placed in the sole of the sports shoe, to record how much a person walks. The product can be connected wireless to an iPod to function as a personal fitness coach.

Figure 96: Nike+iPod is an experimental product that integrates wireless technology in clothing.

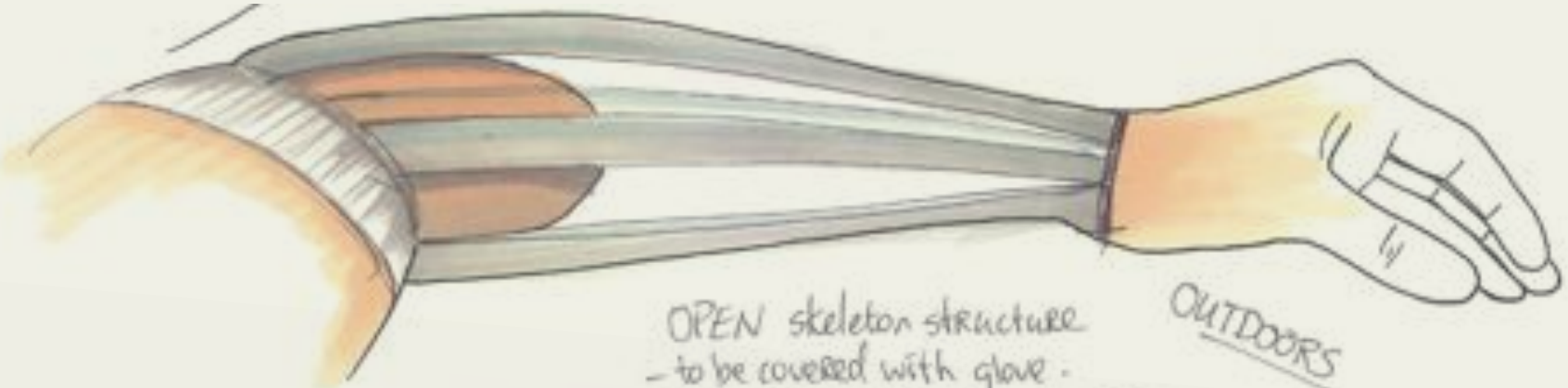
mi adidas
Nike Dunk (PRODUCT)RED™ Low iD
CUSTOMISE FOR A CAUSE
CUSTOMISE YOURS
SHOP THE NIKEID (PRODUCT) RED COLLECTION
49 €
Overhemd op Maat
STOF
DESIGN
MONOGRAM
MATEN
OVERZICHT
Overhemden Designer - Stofkeuze
Kies de stof voor uw overhemden met de dropdown hieronder. U kan selecteren volgens colle
& prijs, kleur, dessin, materiaal, afwerking, structuur... Klik daarna op uw favoriete stof.
Collectie & prijs:
Kleur:
Dessin & patroon:
Materiaal & weefsel:
Afwerking & behandeling:
Structuur:
Alle
Top 10 meest populaire stoffen
Custom T-Shir
Design Online
CREATE IT
Fun &
Online
See how easy it is
CUSTOMISE YOUR ADIDAS
FOOTBALL SHOES
PERSONALIZE

E5: Customization

Formerly, customizing was exclusively for the extremely creative, who had too much time on their hands. School going teenagers participated in this trend by changed the appearance of their boring bags to belong to a certain 'cool' lifestyle group at school. They wrote and drew names on their bags, and used (iron-on) patches and key chains to display their favourite mottos, bands, sports clubs, countries, cities and the like. Especially the plain Eastpak bags are known for their customisable qualities. Nowadays Eastpak embraces these qualities and sells bags that are already 'pre-customised' with unique designs. Eastpak also organises their own bag customising event called 'Tag my pak', where known graffiti artists perform their magic (figure 95).

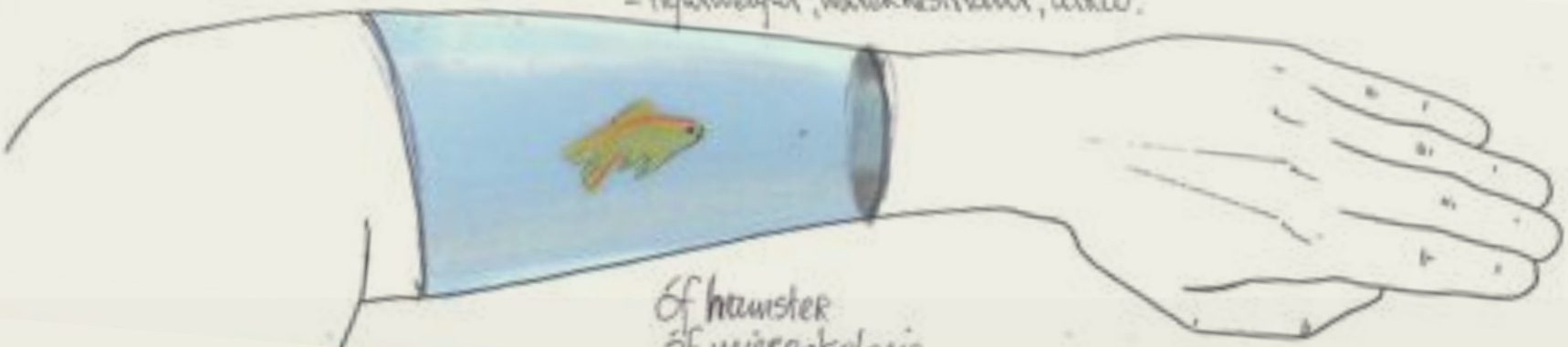
Nowadays online shopping is blooming. Instead of a physical shop, many companies have their webshop as their main sales point. In addition to improved production techniques, this has lead to an increased amount of webshops that allow you to online design or customize your own personal products. Especially clothes and shoes companies are forerunners in this area. Not only specialised webshops (like Bivolino tailor-made shirts, CustomInk.com and Sneakart) venture these services, but also established brands like Adidas, Nike and Converse provide similar customization services to design your own shoes. Amongst the possibility to design your own product, they also offer the possibility to choose customized designs by established artists and other users.

Figure 95: A satisfied teenager at the Eastpak 'Tag my pak' event proudly shows her 'new' backpack.



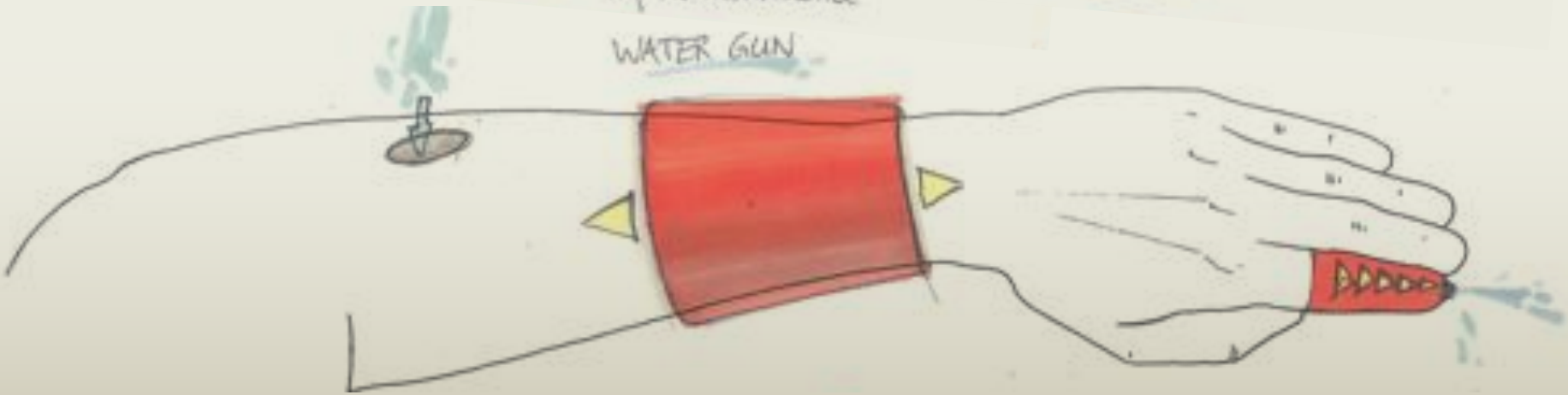
OPEN skeleton structure
- to be covered with glove.
- lightweight, waterresistant, airco.

OUTDOORS



of hamster
of mierenkolonie

WATER GUN



APPENDIX F

IDEA SKETCHES

Left top: Skeleton

In the interviews, Diane talked about getting water in her prosthesis while swimming, which inspired for a few ideas. The first is a wire frame socket, that is supposed to be lightweight and pervious for water, dirt and air. The prosthesis can still be covered by normal gloves if required.

Left middle: Pet arm

Involving very personal details is pictured as a prosthesis that is home to a pet animal, like a goldfish or another small pet. The idea of adding water already has numerous disadvantages, but the idea of adding something extremely personal and beloved like a pet can be very cool for teenagers.

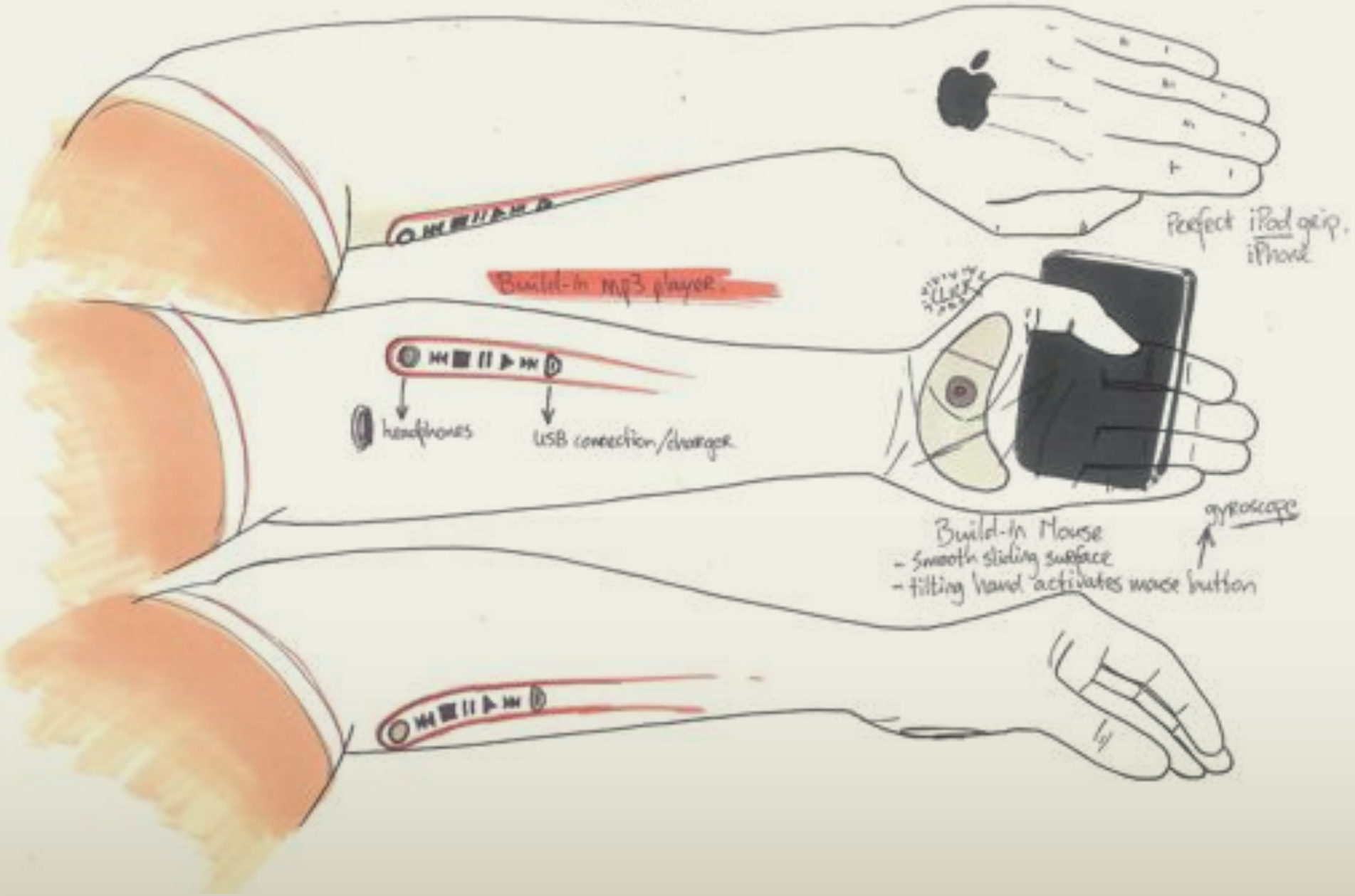
Left bottom: Water gun

A prosthesis with the added functionality of a water pistol, a fun summer activity. The socket is used as a water reservoir, a wristband is used as the trigger and a finger serves as the nozzle.

Right: Gadget fingers

Adding functions can also be interpreted very literally, by adding gadgets to the fingertips of the prosthesis. The fingers are detachable, and cover a gadget tool, like a small light, screw driver, or home key. Almost like the functions of a pocket knife.

iHand


Perfect iPod grip.
iPhone
Build-in mp3 player.
headphones
USB connection/charger
Build-in Mouse
- Smooth sliding surface
- tilting hand activates mouse button
gyroscope

Left: iHand

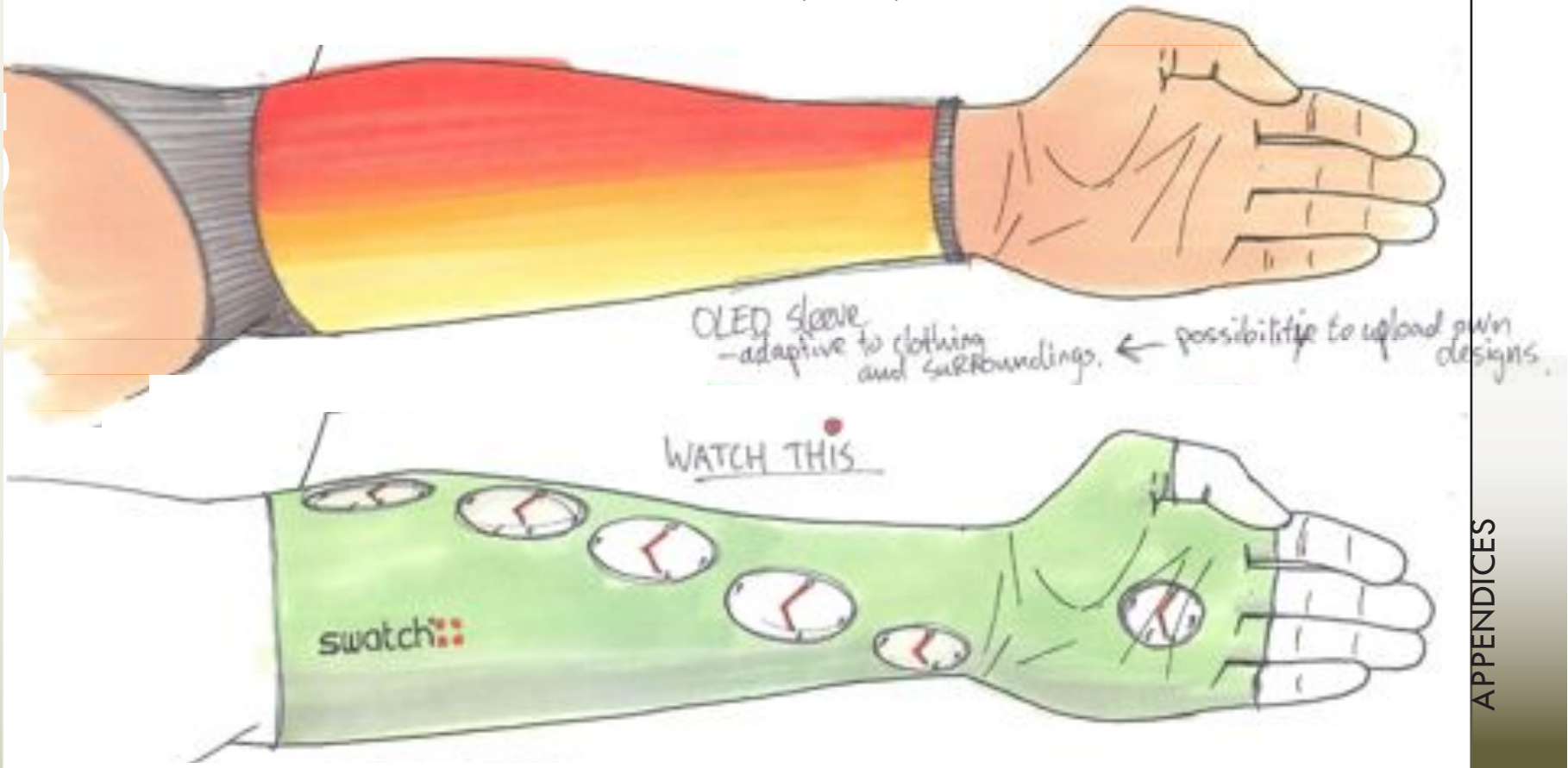
Apple has produced several worldwide gadgets in the last few years. Everything they touch turns into gold, and why not apply this principle to prosthesis, with the Apple iHand. It is a minimalistic design with many functions that relate to other apple products. Music can be stored and played, the hand functions as a computer mouse, and the hand is positioned in order to fit an iPhone.

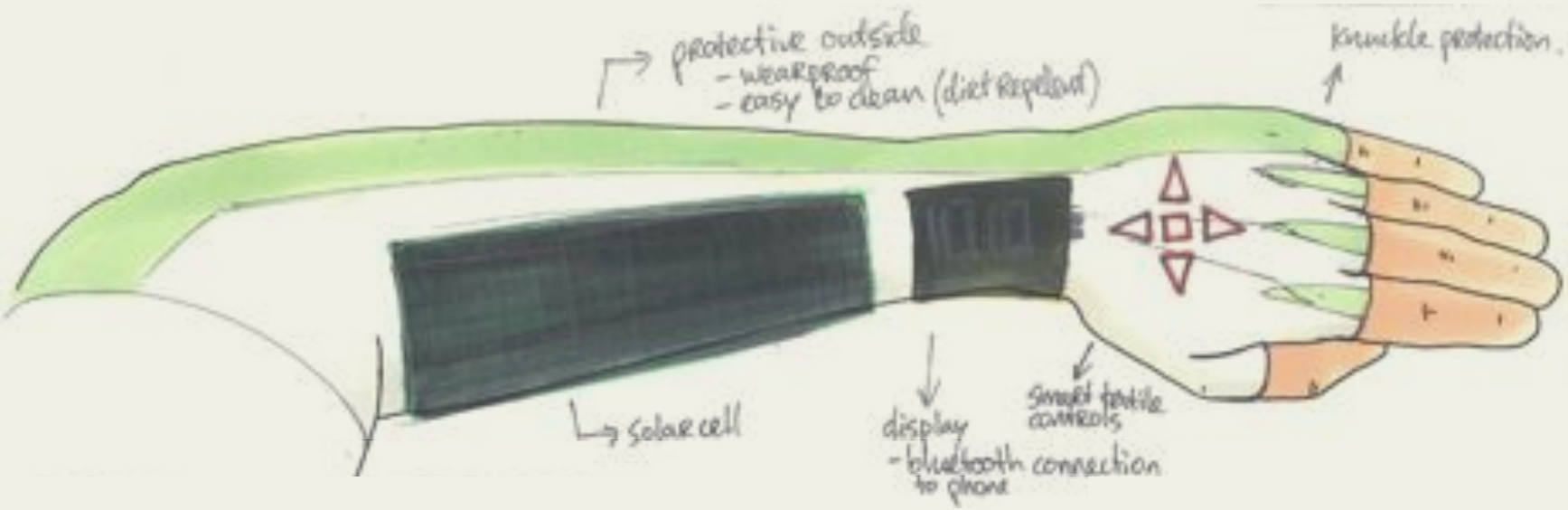
Right top: OLED

A prosthesis sleeve can also distract the attention from the prosthesis. An OLED display that covers the entire sleeve can be used to get a prosthesis with extremely flexible designs. The user can change the appearance to whatever he/she is wearing.

Right bottom: Swatch

Added functionality can also be sought closer to existing arm functions, like carrying a watch. This prosthesis is basically a very large watch strap, with clock faces on all sides. Co-branding with known watch brands is a possibility.




protective outside
- wearproof
- easy to clean (dirt repellent)
knuckle protection.
solar cell
display
- bluetooth connection to phone
smart textile controls

lots of text, since this is an eReader.
other interesting texts might also be displayed here.
internet feeds, email, text messages? who knows...
it might even contain an agenda but the option to
save notes and the like, and more's.
eReader

Left top: Second screen

The prosthesis can be made more advantageous by integrating technology. This prosthesis has a solar cell to supply power for the display and controls. The device is connected with bluetooth to a phone or mp3 player, and functions as a second screen to operate these devices. If there is no device connected, only the basic options are available, like a clock and a fun mini game.

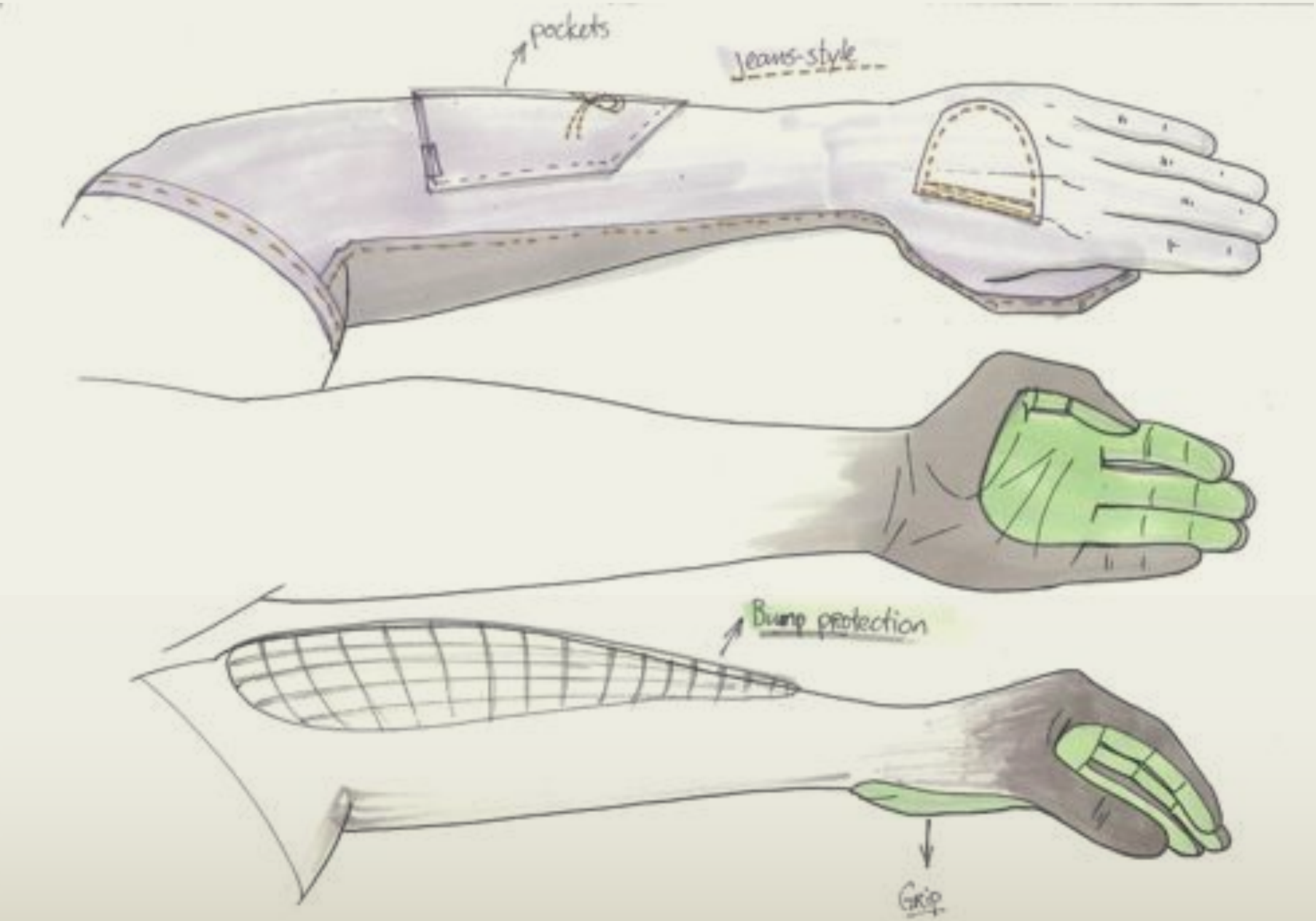
Left bottom: eReader

This sleeve is in fact the screen of an eReader. Despite the obvious functions of reading books, magazines and other texts, the reader might also be used to display the latest e-mails, text messages, tweets, hyves messages and other internet feeds.

When not in use, the sleeve can be used to display decorative greyscale images and patterns. An additional advantage of this screen is the low energy consumption.

Right: Mp3 storage

Quite similar to the left top prosthesis, only a more stand-alone mp3 player, with a display The prosthesis can be connected to other devices with bluetooth and USB, and has its own build-in storage for music and other data. The prosthesis contains a one line display to show Mp3 information, but also to add the functionality of reading incoming text messages and e-mails from a bluetooth connected phone. Additional to the solar cell, the USB connection is used for charging.


pockets
jeans-style
Bump protection
Grip

Left top: Denim

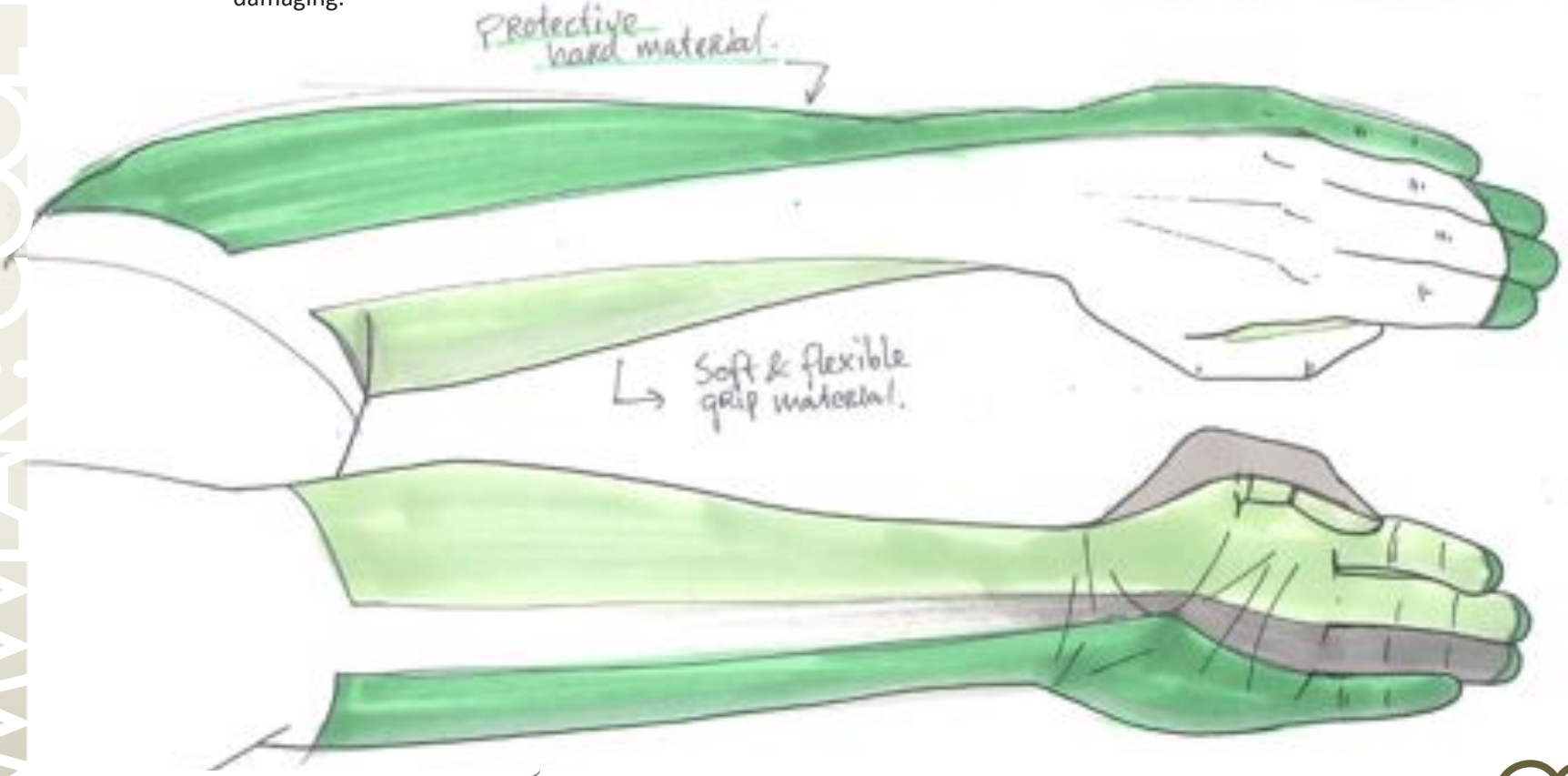
A prosthesis glove does not necessarily have to be skin-coloured plastic. This plastic has several disadvantages, which can be solved by changing the material. For instance a denim glove can have more durability and resistance against wearing, dirt and stains. It will fit to worn jeans, and it can be washed with other clothes just as easy.

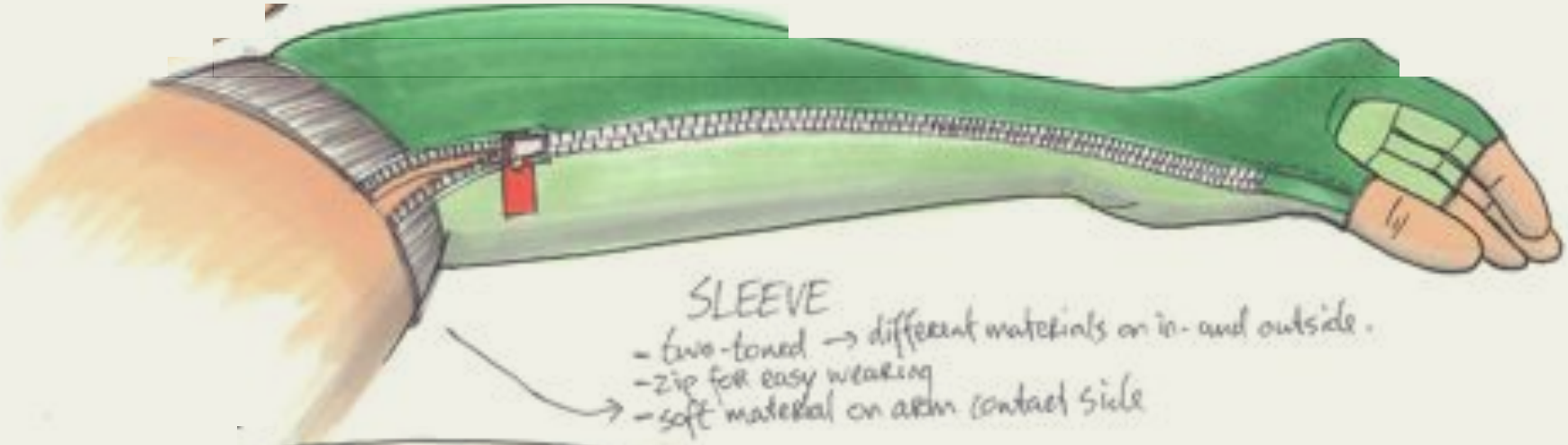
Left middle & bottom: Grip and protect

On a normal arm, skin has different functions. The palm of the hand needs to have more grip, while the outside of the arm will need more bump protection. The prosthesis can be adjusted to prevent wearing and damaging.

Right: Emphasise function

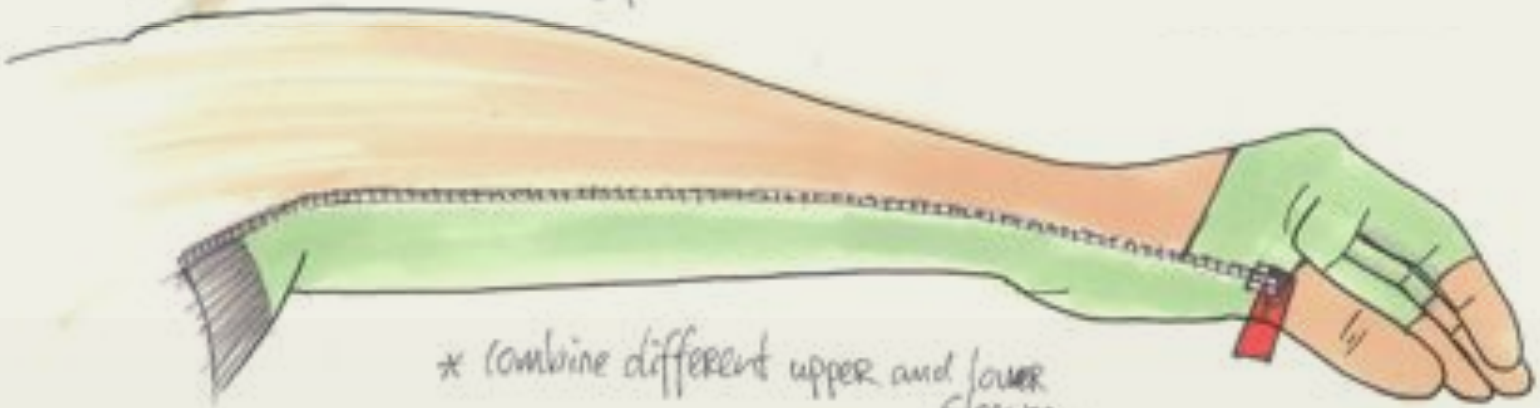
The inside and outside of the arm have different functions, resulting in different skin characteristics. This fact can be exaggerated in a prosthesis as well, with different materials and colours on the in and outside. This prosthesis is another version of applying different materials and functionality to the inside and outside of the arm.



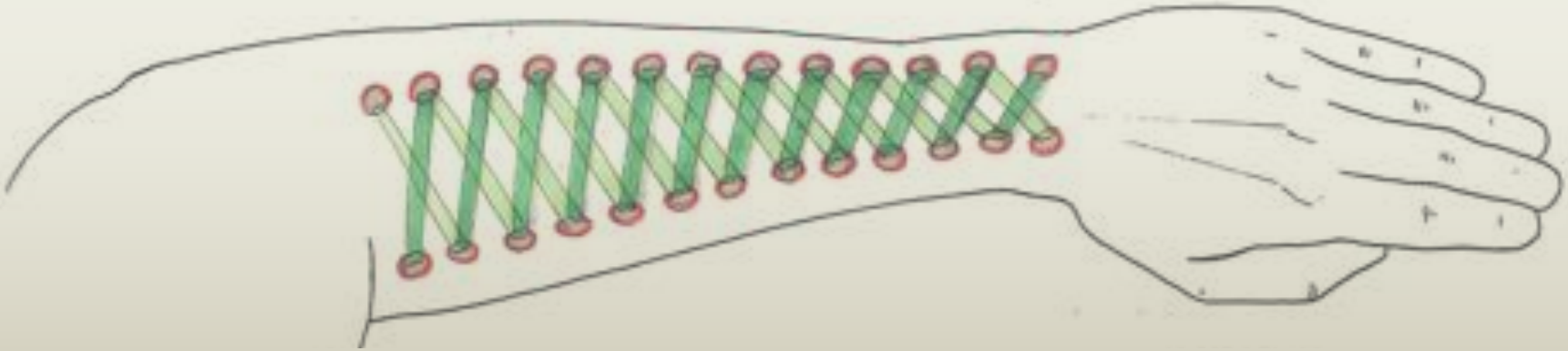


SLEEVE

- two-toned → different materials on in- and outside.
- zip for easy wearing
- soft material on arm contact side



* combine different upper and lower sleeves.



Left: Zip & Combine

This idea combines customisation and the exaggeration of arm functions. Two parts of different materials are zipped together to form the glove. As an additional advantage, this glove is much easier to put on than a regular glove.

The middle image shows how the outer part of the glove is removed, so that another one can be zipped on. This can be very easy and fast when changing activities on a regular day. Every activity can have their own specialised gloves, to allow better functionality and protection. If desired, the glove can also still be removed.

Left bottom: Accessible accessories

There are also other possibilities to attach different parts of one glove. Magnetic, elastic, laces, buttons, press-studs, Velcro, hooks and layers. This example shows what laces might do to the appearance of an arm. Laces have the advantage of again being very easily replaceable and thus personalisable.

An important thing to keep in mind is that a prosthesis wearer with only one hand must be able to put it on. Fortunately, these people are very skilled with one hand, but if a glove would be based on inclusive design, normal people

Right: Add and customize

Another idea is about having people personalise their products themselves, more actively. This could be done by offering a quite neutral design, in which the user can change some details. For instance by adding a strip of fabric of (old) clothes. The user can make/choose their own unique designs. Additional limited edition strips might also be available with other products (shoes, clothes) and from various brands.

glove with
skin colored hand.
appears to be
a sleeve
skin colored fabric
TWO GLOVES
- prosthesis
- & healthy hand.

Left top: Sleeve

Shows a prosthesis glove made entirely out of fabric. The sleeve clearly appears as a piece of clothing, but even the skin coloured hand is qualitative fabric.

Left bottom: Two gloves, two hands

A glove without fingers will attract attention, but only to the glove. The skin coloured cosmetic glove will be slightly visible, and it will appear like there is a normal hand underneath the glove. This can be exaggerated more when a similar glove is worn on the healthy hand.

This way, the glove might even also be worn by healthy people, increasing the popularity and target market of the new product.

Right: Design your own

Customising and personalising can be done easily through internet. This way prosthesis wearers can design their own prosthesis gloves to exactly match their individual wishes, and order them wherever they want whenever they need.

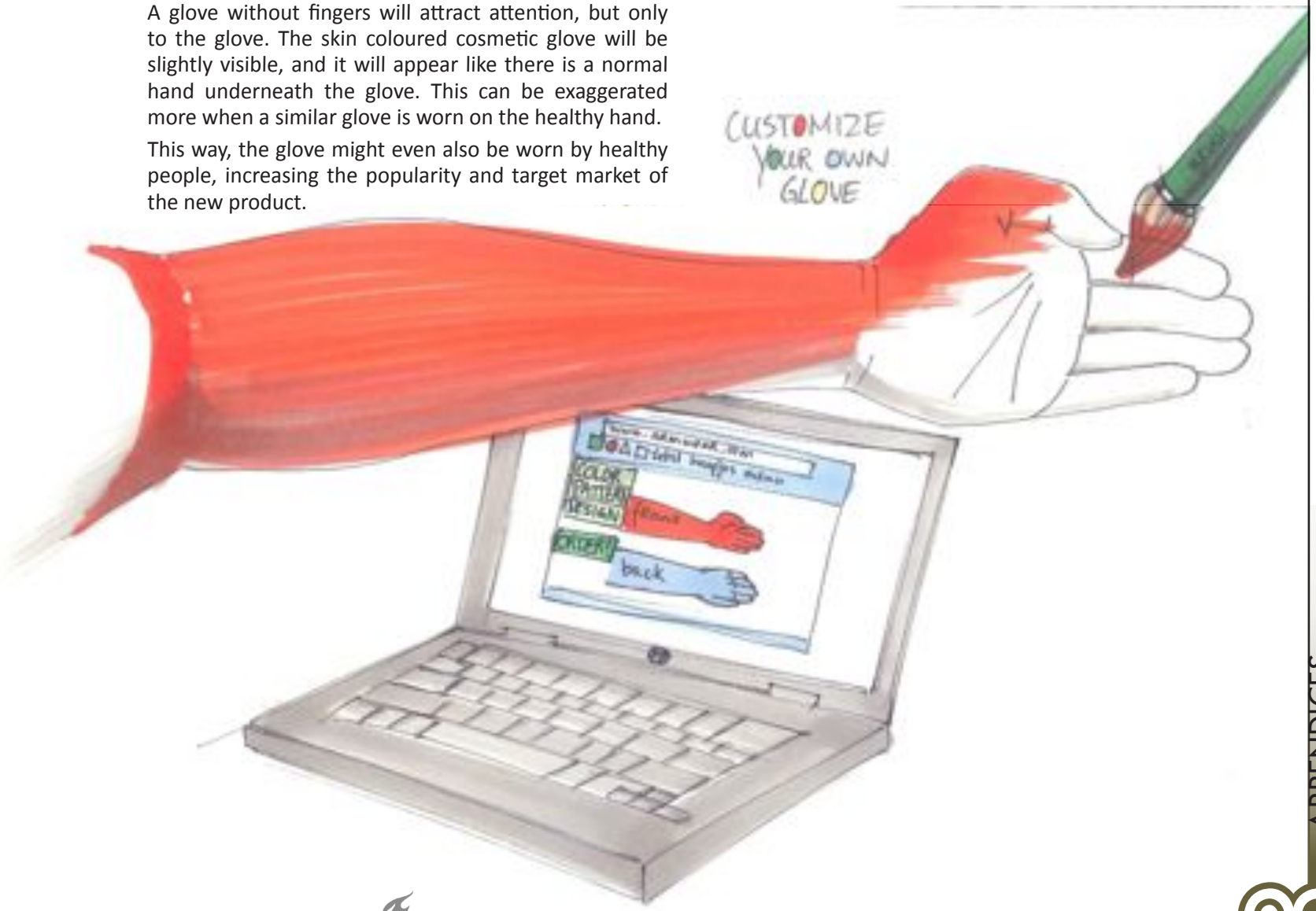


Figure 112: Detailed research data from study two, containing the average results for all the emotions with all participant groups.

TOTAL	Avg Positive	Desire	Satis-faction	Pride	Hope	Joy	Fasci-nation	Avg Negative	Disgust	Dassatis-faction	Shame	Fear	Sadness	Boredom
Cosmetic Glove	2,19	1,8	2,2	2,3	1,7	2,7	2,4	1,39	1,6	1,5	1,3	1,4	1,3	1,3
Puma green hand	2,17	1,9	2,2	2,3	1,8	2,3	2,5	1,31	1,5	1,5	1,4	1,2	1,0	1,2
Appealing Prehensor	1,72	1,3	2,1	1,9	1,5	1,8	1,8	1,73	1,9	1,9	1,6	1,9	1,5	1,6
Immaculate	1,74	1,6	1,9	1,5	1,5	1,9	2,0	1,56	1,7	1,5	1,6	1,5	1,8	1,3
Integro	2,04	1,9	2,1	2,2	1,5	2,3	2,3	1,23	1,2	1,1	1,3	1,3	1,3	1,2
ArmWear	2,27	2,1	2,6	2,4	1,9	2,4	2,3	1,26	1,1	1,4	1,5	1,2	1,2	1,1
Di Guardi	1,90	1,8	2,0	1,9	1,4	2,2	2,0	1,15	1,1	1,1	1,2	1,2	1,1	1,2

PEERS	Avg Positive	Desire	Satis-faction	Pride	Hope	Joy	Fasci-nation	Avg Negative	Disgust	Dassatis-faction	Shame	Fear	Sadness	Boredom
Cosmetic Glove	2,23	1,9	2,3	2,4	1,7	2,7	2,4	1,56	1,8	1,7	1,4	1,5	1,4	1,5
Puma green hand	2,32	2,1	2,3	2,5	2,0	2,4	2,6	1,43	1,6	1,6	1,6	1,3	1,1	1,3
Appealing Prehensor	1,97	1,6	2,3	2,1	1,7	2,0	2,1	1,84	1,9	2,1	1,8	2,0	1,7	1,6
Immaculate	1,90	1,8	2,0	1,7	1,7	2,0	2,2	1,70	1,8	1,6	1,8	1,6	2,1	1,3
Integro	2,05	1,9	2,0	2,3	1,6	2,3	2,2	1,42	1,3	1,3	1,6	1,4	1,5	1,4
ArmWear	2,27	2,1	2,6	2,4	1,9	2,4	2,1	1,47	1,3	1,6	1,7	1,4	1,4	1,3
Di Guardi	1,94	1,9	2,0	2,0	1,5	2,2	2,0	1,36	1,3	1,3	1,4	1,4	1,3	1,4

WEARERS	Avg Positive	Desire	Satis-faction	Pride	Hope	Joy	Fasci-nation	Avg Negative	Disgust	Dassatis-faction	Shame	Fear	Sadness	Boredom
Cosmetic Glove	1,97	1,6	1,6	2,0	1,4	2,6	2,6	0,50	0,4	0,8	0,6	0,6	0,4	0,2
Puma green hand	1,33	1,0	1,6	1,0	0,8	1,6	2,0	0,70	1,0	1,4	0,6	0,4	0,4	0,4
Appealing Prehensor	0,40	0,2	0,8	0,4	0,2	0,8	0,0	1,17	2,0	0,8	0,8	1,6	0,4	1,4
Immaculate	0,90	0,8	1,2	0,6	0,6	1,2	1,0	0,77	1,2	1,0	0,6	0,8	0,2	0,8
Integro	2,00	1,8	2,6	1,6	1,2	2,4	2,4	0,23	0,4	0,2	0,0	0,6	0,0	0,2
ArmWear	2,27	2,0	2,6	2,0	1,8	2,4	2,8	0,13	0,2	0,4	0,2	0,0	0,0	0,0
Di Guardi	1,67	1,6	2,0	1,4	1,2	2,0	1,8	0,03	0,0	0,0	0,0	0,2	0,0	0,0

APPENDIX G

STUDY 2: DETAILED DATA

These graphs show an overview of the average values for all the emotions measured in the PrEmo research (figure 112). The six positive emotions and one overall value are accentuated in green, and the six negative emotions and an overall value are red.

The top figure shows the values for the total number of participants, while the other images give an overview of just one of the participant groups.

Within the figures, the extreme values are also accentuated. Green for a the most positive prosthesis, and red for the most negative result.

The 7 prostheses are sorted in the three prosthesis groups: 4 reference prostheses and 3 concept designs.

The data was collected from the input of 27 participants: 5 prosthesis wearers and 27 teenage peers.

Figure 113a: To transfer the sewing patterns onto the material, a paper cutout can be used to create the outlines of the part.

APPENDIX H

BUILDING INSTRUCTIONS

Preparation

1. Start with measuring the size of the prosthesis hand. And determine if all the sewing patterns have to be mirrored and scaled to the right size.
2. Use the sewing patterns to cut all the parts in the desired materials. After this preparation, the actual sewing can begin (figure 113a,b).

Glove

- Note: The glove is created inside-out, and turned outside-out in step 8.

3. It is easiest to start with the ArmWear glove, by sewing the neoprene (9, 10) onto the corresponding denim shapes (6, 7). The neoprene is more difficult to handle in a later stadium.
4. The next step is finishing the thumb (7), and attaching it to the palm (6).
5. Now we start with the fingers. The 90 cm cotton spacer (4) is basically the side material for all the fingers. It is lined up to the contours of the hand (6): starting at the wrist at one side, following the fingers and ending at the wrist on the other side.

- Note: Please mind the stretch direction of the cotton, this must be perpendicular to the length of the spacer.

6. Attach the black Velcro (2) in the desired area on the denim outside of the hand (8) to determine where the DYO-patches can be stuck.
7. Repeat step 5 to attach the outside of the hand (8) to the cotton spacer (4), to complete the basic shape of the glove.

Now the zipper (3) can be mounted on. Cut the glove open from the wrist (6) to the thumb (7) on the desired path. And attach the zipper (figure 113c).

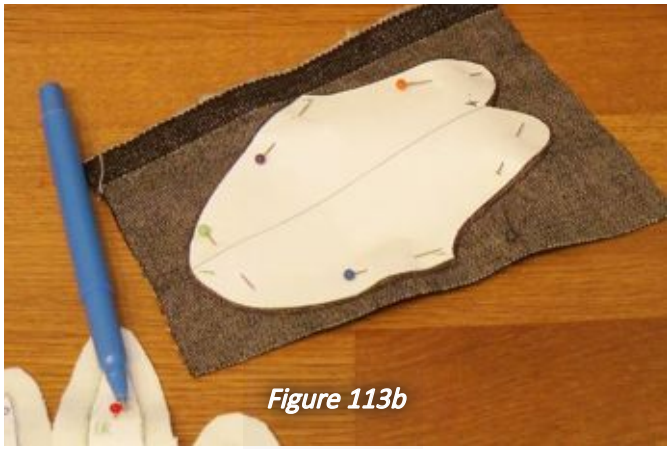


Figure 113b

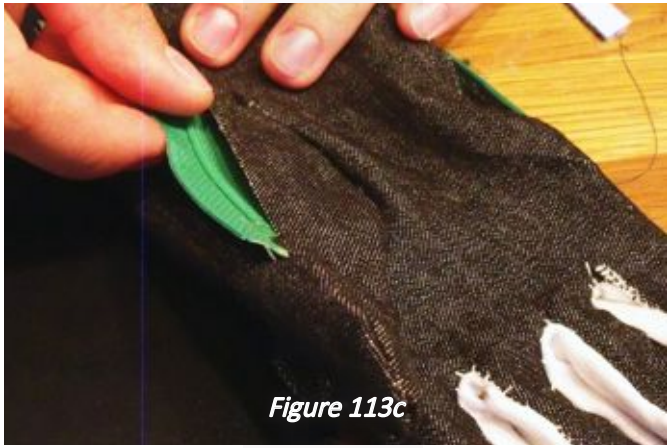


Figure 113c

Figure 113d

Figure 113e: Sewing has to be done very precise, in order to maintain a good fitting.

8. At this point, all the fingers and the thumb are finished, and the glove must be turned outside-out (figure 113d)
9. The final step in finishing the glove is to create the cuff for a nice fitting at the wrist. The cuff is created separately to secure a good fitting, and sewed to the glove afterwards (figure 113f).

- Note: Again, mind the stretch direction of the cotton, this must be in the direction of the circumference of the wrist.

Elbowcover

- Note: The elbowcover contains less parts than the glove, and is easier to make. Nevertheless it is important to create a shape that allows a tight fitting even on a bended elbow.

10. Start with attaching the neoprene elbow grasp (13) to the mid-section of the denim outside (16) (figure 113g).
11. Then all the other denim links (14, 15, 17) can be attached to the sides of the mid section (16).
12. Attach one strip of black Velcro to the outside of link 1 (14).
13. The last part is the cotton closing strap (18), to complete the elbow circumference. One side of the strap is sewn to link 4 (17) of the denim, while the other side is finished off with four strips of white Velcro (figure 113g). Two strips on the outside for the DYO-patch, and two strips on the inside for the closing mechanism.

DYO-Patches

14. Creating the DYO-patches involves nothing more than sewing two strips of Velcro on the desired patch material (figure 113h). Make sure the size and position of the Velcro corresponds with the area it is supposed to cover on the glove or the elbowcover.

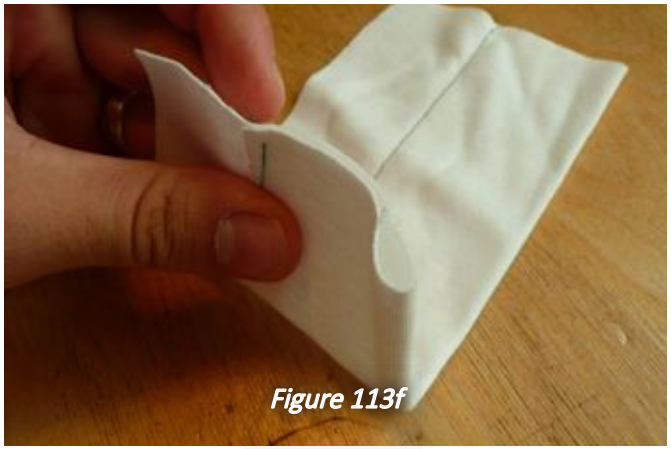


Figure 113f

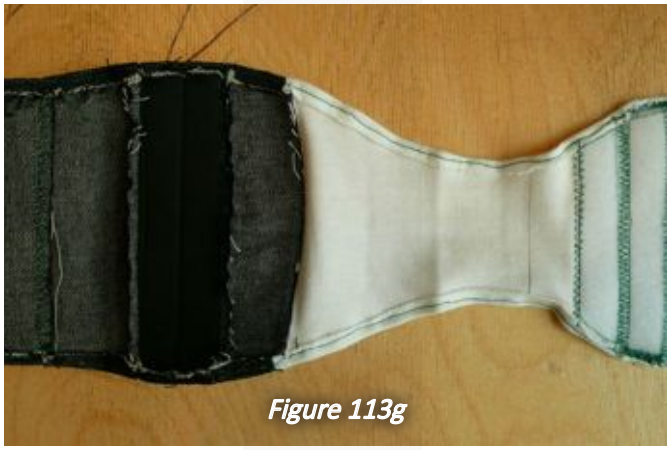


Figure 113g

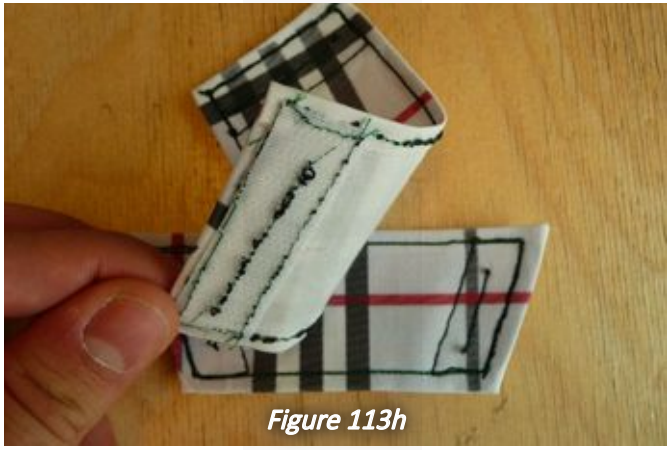
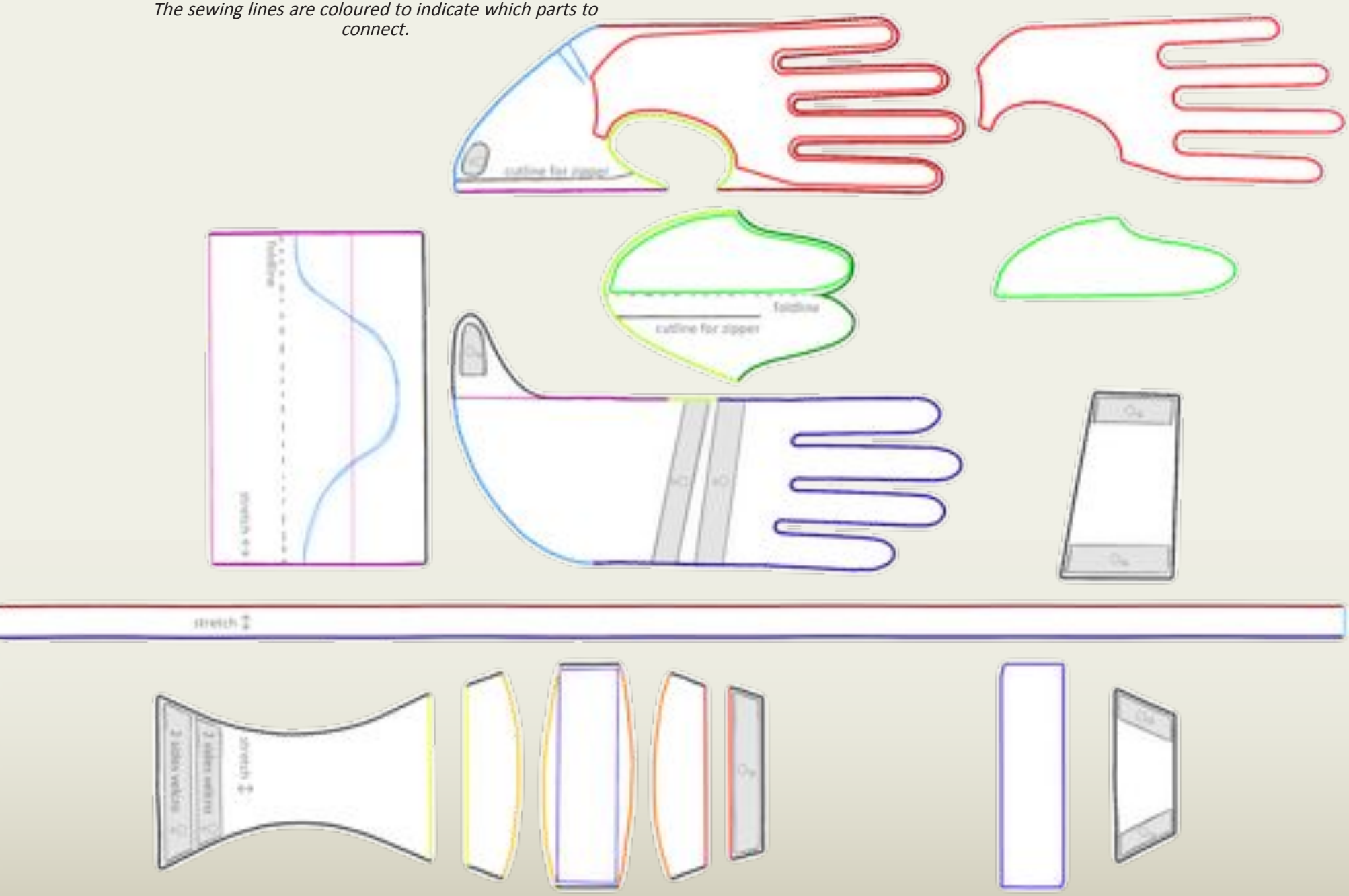


Figure 113h

Figure 114: Sewing patterns suitable for production. The sewing lines are coloured to indicate which parts to connect.



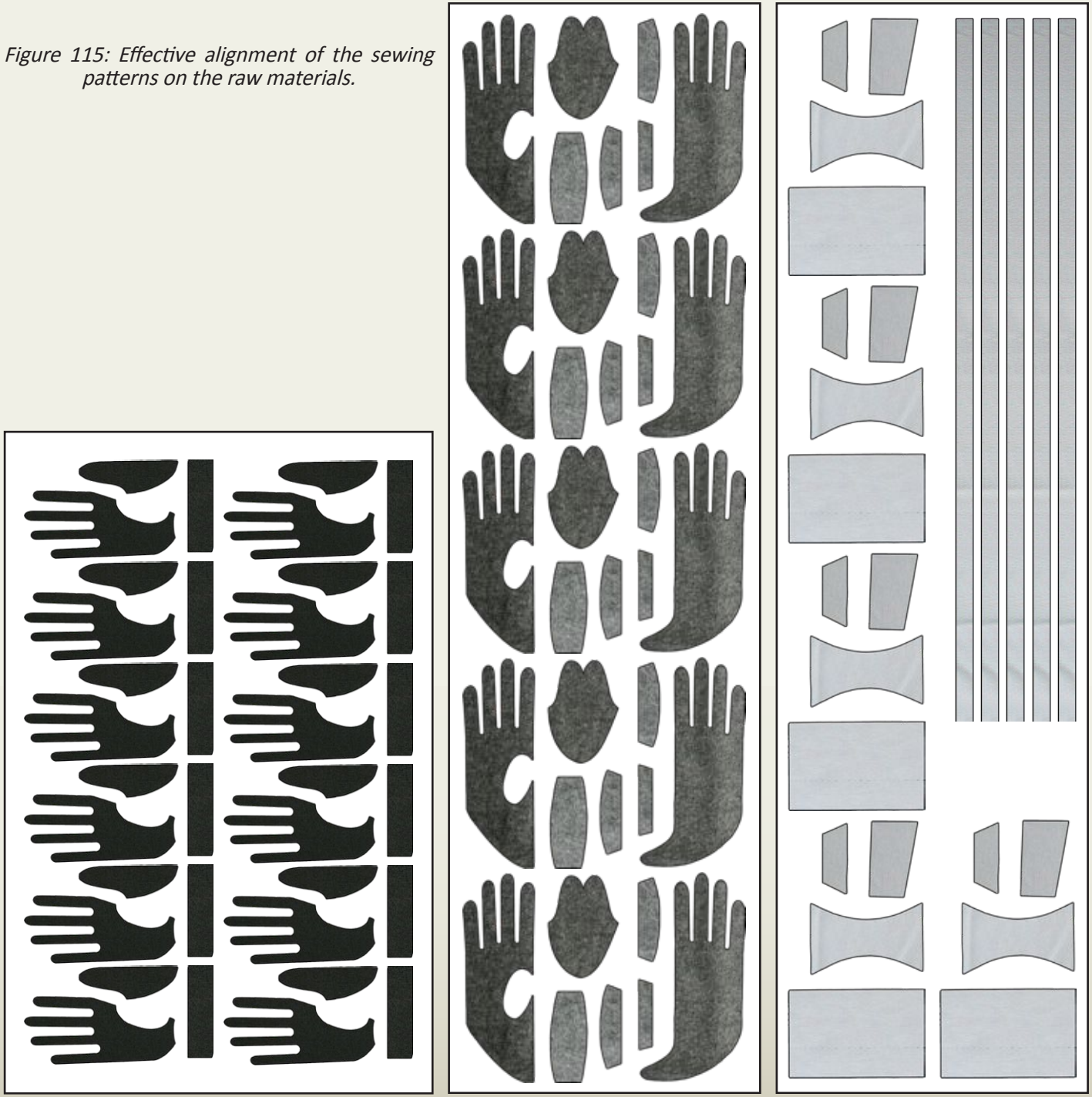
APPENDIX I

SEWING PATTERNS

These are the sewing patterns belonging to the building instruction for the ArmWear products, which can be found in appendix .

- The digital file can be used to easily scale and mirror the patterns to the right size, based on the hand size of the wearer (hand print). The file can be found on the report DVD.
- Please note that all the sewing patterns exclude a necessary sewing margin of about 5 to 10 mm.
- The sewing pattern for the ArmWear glove is rather complex, therefore the line colours on the patterns indicate which parts to connect.
- The cotton spacer, which is used to connect the from and the back of the glove is a very long stretch of cotton. The length can be up to 90 cm for a large prosthesis, dependent on the scale of the glove.
- Please note the stretch direction for a good fitting.
- The position of the Velcro is indicated by the grey areas. Velcro always connects two parts. The soft parts are indicated with a ♀, and the corresponding rough parts are indicated with a ♂.
- Please note that two strips of Velcro on the elbowcover have to be attached on both sides of the material, resulting in a total of four strips.

Figure 115: Effective alignment of the sewing patterns on the raw materials.



APPENDIX I

EFFICIENT ALIGNMENT

The figures on the left show an effective alignment of the sewing patterns on the raw materials, on which the ideal alignment depends.

Denim and cotton

The denim and cotton fabric is generally available on rolls with a width of 1400mm. The alignment on the left shows how 5 gloves could be produced of 400x1400mm of cotton and an equal amount of denim. On average, this means that as little as 0,11m^2 denim and cotton is required for each glove and elbowcover.

Neoprene

Since neoprene is not really a fabric, the raw form is sheets with dimensions of 850x550mm. Ideally aligned, 12 gloves can be made from one sheet of neoprene. Which means 0,04m^2 is required for each glove and elbowcover

Velcro

To match nicely with the other materials, white and black Velcro is used. Velcro is available on rolls, varying in width. For the ArmWear a width of 20mm is used. Including both sides of the Velcro fastening, 0,4m white Velcro and 0,24m black Velcro is used.

Figure 102: A craftsman tailoring in his workshop.

APPENDIX J

EXPERT INTERVIEW

Tailors in The Hague

To oversee the production possibilities, several independent tailors in The Hague were asked about the expected production costs of the ArmWear glove.

Three tailors in the city centre of The Hague have been asked for their opinion: *Shilo Tailoring*, *Haagsche Tailor* and *Tip Top.*

They showed completely different responses, with the conformity that they all were quite surprised with such a request. Their daily routine mainly deals with repairing and mending clothes, and even so gloves are rare. They all felt more comfortable giving a price indication after the first build.

Shilo Tailoring

This tailor appeared to be the cheapest, since the workshop was also the living room of the African owner of the shop. The owner estimated that making a glove would cost about 2 to 3 hours, which put the production costs at about €12,50. When I received his business card he mumbled something about the taxes, which questions the legality of his business even more so. But All in all, he was very much willing to produce the ArmWear gloves for a very low price, if I would supply the materials.

Haagsche Tailor

The authenticity of this tailor was overwhelming. The shop was ran by a friendly gentleman with a Middle Eastern appearance and a tapeline around his neck. He was very much specialised in repairing clothing, and did not really know what to make of my request. His machinery would be unfit for the zigzag stitch, which means a lot of manual labour, which means a very high price. Even if the materials would be supplied, the costs would be around €50.

Tip Top

Tip Top is a dry-cleaning service who also claims to repair clothing and even design suits. The store manager thought it was a strange request, which became even stranger when I asked for only one glove, and not a pair. He questioned if he could possibly do it with his limited recourses and machinery, but he thought production for a pair would cost about €40 euro, and one glove would be around €25. He also told about a special sewing machine for making gloves. Production would be a lot cheaper with such a machine, and unfortunately he did not have such equipment, or knew somebody who did.

Conclusion

Of course, a tailor like Shilo could be asked for a 'pilot test', to see the actual quality and cost of his work. The low price seems work the chance.

But the best chance for a qualitative yet reasonably priced production partner should be extended to a wider area, and focus on professional tailors who have experience with gloves, and who might even own specialised sewing equipment to make gloves.

ArmWear: Cool Prosthetics
Marijn Geurts
Elbow cover
Arm Prosthesis
Glove
Wat? Mijn afstudeerpresentatie! :)
Wanneer? Dinsdag 14 september, 15:45u
Waar? Faculteit 10, Bernd Schierbeekzaal
TomTom? Landbergstraat 15, 2628 CE, Delft

PROJECT DVD

Marijn Geurts
DFI Medisign, Sept.2010

TU Delft Dr. Ir. Pieter Desmet
Dr. Ir. Johan Molenbroek

DIPO Delft Institute of Prosthetics and Orthotics
Dr. Ir. Dick Plettenburg

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