Mapping the future of protective hand-exoskeletons

Market identification and branding strategy development

Master thesis

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Executive Summary

In 2011, the world watched in amazement how IBM's AI named Watson won at *Jeopardy!*. Right afterwards, IBM decided to use this power to revolutionize the healthcare system. AI doctors would change everyone's lives. Sadly, Watson did not revolutionize healthcare. It did not prove to be as useful in reality as was anticipated[1].

How could this happen?

In short, IBM started with a very specific use case, then invented a super high-tech solution for it, and then started wondering how it could actually be useful[2].

This example actually illustrates the problem that CrossGuard has. Luckily, CrossGuard's problem is multiple orders of magnitude smaller than it was for IBM.

CrossGuard is a company that has developed a protective glove for so-called Historical European Martial Arts (HEMA), or medieval sword fighting. The glove is called the ProGauntlet. It has been designed to withstand high-impact blows from steel swords repeatedly, to protect the users' hands from virtually any type of impact during HEMA.

Not only do they protect very well, they also let the user move their hands naturally, without restricting the freedom of movement. It is the ultimate HEMA glove, but as the HEMA market is relatively small, CrossGuard wants to make the ProGauntlet useful for other purposes, too. Therefore the aim of this project has been to find the next market for the ProGauntlet.

This is where IBM's example comes in. Just like Watson, the ProGauntlet is a technological solution that is looking for a problem to solve. The initial aim of this project was precisely this: finding another market for the ProGauntlet.

The research method consisted of a product analysis, literature research and user research, mainly in the form of interviews. The most promising markets were researched in-depth: ice hockey, field hockey, lacrosse, kendo, Filipino Martial Arts (FMA) and motorcycle riding. Of these, the only people that would benefit from the ProGauntlet (besides HEMA) is a certain niche of the FMA. This group consists of about only 500 people, so this is a nice addition to the total market for the ProGauntlet, but it definitely isn't a sustainable market for CrossGuard.

Since there is no viable future market for the ProGauntlet, the main focus of this project has become to determine the most interesting market in which to introduce a redesigned protective glove. Based on the research, this appears to be field hockey.

Therefore, a strategy for entering the field hockey market is proposed. The most important quality of a field hockey glove should be that it does not restrain the user in any way.

The suggested positioning for the field hockey market is therefore: ***unrestrained protection***. A great advantage of this positioning is that it could also work for the ProGauntlet and simultaneously opens a clear path to future innovations for CrossGuard.

REAL-WORLD IMPLICATIONS

Partially due to this research, CrossGuard has started developing a glove for field hockey.

[1] https://spectrum.ieee.org/biomedical/diagnostics/how-ibm-watson-overpromised-and-underdelivered-on-ai-health-care

[2] In reality, it is a bit more nuanced of course, but this does appear to be one of the underlying causes.

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1. Introduction

Introduction

This project is done in collaboration with CrossGuard.

CrossGuard is a company that has developed a protective glove called the ProGauntlet. These gloves work like an exoskeleton that protects the hands against hard impacts without restricting the freedom of movement.

The ProGauntlet has been designed for Historical European Martial Arts (HEMA), also known as or medieval sword fighting. It has been designed to withstand high-impact blows from steel swords repeatedly, to protect the users' hands from virtually any type of impact caused by the these swords. Without adequate hand protection, these blows would easily cause serious injuries. The ProGauntlet has been designed to offer an extremely high level of protection against repeated impacts.

CrossGuard has chosen for the market HEMA market particular due to the personal interest of the founders, whose passion has been the starting point of their quest to design the ultimate HEMA glove. The company has been developing the gloves for about six years now. They are shipping their first batch of pre-orders at this moment.

PURPOSE OF THE PROJECT

The ProGauntlet is an impressive product. It incorporates an extremely high degree of impact protection in a relatively slim and light package, while retaining nearly unobstructed freedom of movement of the fingers. This combination of qualities might be of great value in other markets where impact protection and freedom of movement are necessary.

The purpose of this project is to determine in which market(s) CrossGuard can launch the ProGauntlet, if any.

CrossGuard is highly interested in this type of research; they even called it "essential to the future of the company". The HEMA market consists of an estimated 30,000 consumers worldwide. This is much less than CrossGuard had initially estimated, which was around 65,000 consumers worldwide. This makes this project even more important for the future of the company.

According to CrossGuard the HEMA market is large enough for the company to run a sustainable business, but they will need to increase their market size in order to let the company grow.

CrossGuard has invested a lot of time and resources into the current design and production process of the ProGauntlet. In the original design brief, the company had therefore made clear that the technical changes in the design should be kept to an absolute minimum, preferably none at all. A redesign should only be considered if this would be essential to sell the gloves in a different context or for a large market.

RESEARCH QUESTION

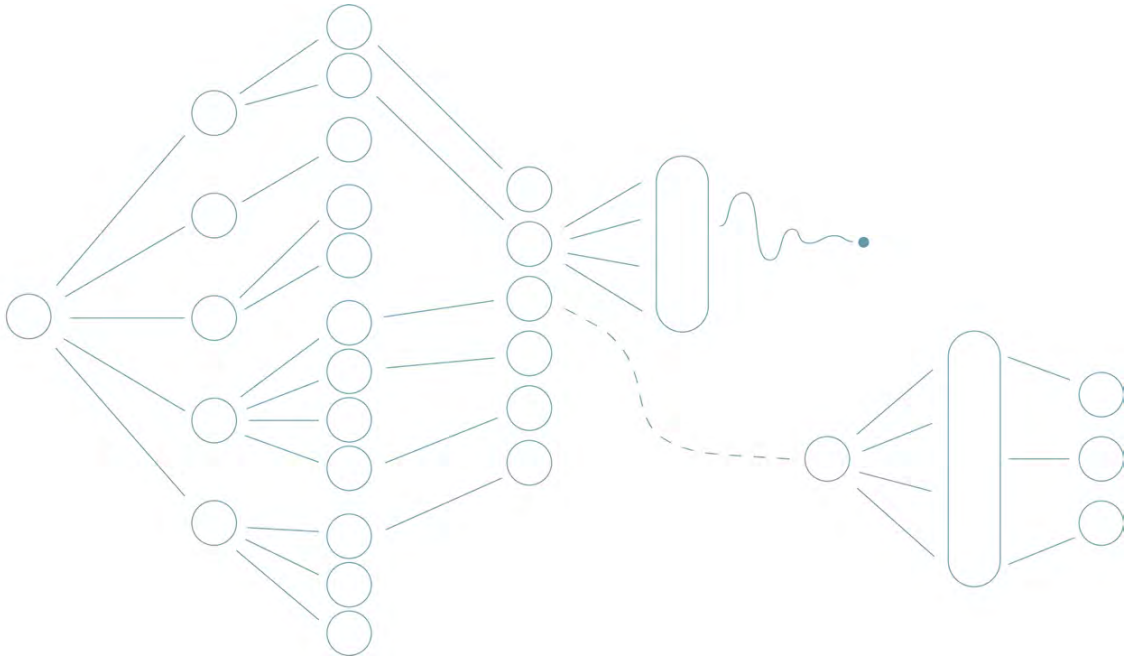
- Is there another market, besides the HEMA market, in which CrossGuard can sell the ProGauntlet?
  - How should CrossGuard approach this market in terms of branding?
  - If there is no other viable market for the ProGauntlet, then what is the most promising market for a redesigned glove?
- The original project brief can be found in appendix 1

REPORT STRUCTURE

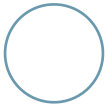
In this report, the potential markets are analyzed and selection is made, in order to give strategic advice to CrossGuard.

This has happened through a combination of literature research, user research and some real-life testing. The markets that are researched in-depth are: ice hockey, field hockey, lacrosse, kendo, Filipino martial arts and motorcycle riding.

The research methods are described in the next section, followed by a more detailed description of the context of HEMA. Afterwards, the most important results of the market exploration are discussed. The full analyses are found in appendix 2 and 4. Based on the results, the next steps for entering another market are determined. After determining the next market for CrossGuard, the branding strategy for the market in question is described in the following chapter. At last, recommendations for the future of CrossGuard are made.



2. Project context



What is the ProGauntlet?

The ProGauntlet is a protective glove with a hard outer shell. Although the ProGauntlet is usually referred to as a glove, the term "exoskeleton" is actually more appropriate. Its hard outer shell consists of many overlapping scales that follow the anatomy of the hand closely, and allow for a complete articulation of all joints in the hand. In other words, it protects the hands against impacts very well without restricting the freedom of movement.

Image credit: CrossGuard

The ProGauntlet has been designed for Historical European Martial Arts (HEMA). This is a highly specific context with its own unique set of requirements, user needs and wishes, all of which have influenced the design.

It has been designed to withstand high-impact blows from steel swords repeatedly, to protect the users' hands from virtually any type of impact caused by the these swords. Without adequate hand protection, these blows would easily cause serious injuries. The ProGauntlet has been designed to offer an extremely high level of protection against repeated impacts.

Image credit: CrossGuard

What are Historical European Martial Arts?

The focus of HEMA is on reproducing the combat techniques that were used in the martial arts of medieval Europe. It encompasses a number of different styles of fighting and fencing. Many of these techniques were practically forgotten until around the 1990's, when people started regaining interest. The knowledge of today is largely based on fencing treatises dating back as far as the 14th century AD [1, 2].

The injury profile of HEMA is different from other armed martial arts. In combat, people mainly use their swords, but certain grappling techniques are also allowed, making it similar to unarmed martial arts like judo in some ways [3]. The types of hand protection that have been used up until now either don't offer enough protection, or limit the freedom of movement too much. In both cases, the performance and safety are impacted negatively. The ProGauntlet appears to solve the problem very effectively by offering full protection and almost unrestricted freedom of movement at the same time. According to the people at CrossGuard, the ProGauntlet allows HEMA practitioners to use other techniques that are either too dangerous or physically impossible with other gloves. This allows the players to mimic the techniques that were originally used for medieval sword fighting more closely.

Market size

Official statistics on HEMA participation are lacking, as it started gaining popularity only recently. Prior to this project CrossGuard has made an estimation of the total market size, based on reports from HEMA clubs and enthusiasts around the world. CrossGuard had initially estimated that the HEMA market consists of about 65,000 users worldwide, but the most recent estimations are less optimistic unfortunately. These suggest that the HEMA market only consists of around 30,000 users worldwide. This has become clear while this project was already in progress, and this new information makes this report even more relevant for the company.

Consumers of the ProGauntlet

The ProGauntlet is mainly aimed at HEMA enthusiasts. These people spend a considerable amount of time and energy on HEMA and are likely affiliated with a HEMA group or club. Some of these people also compete in tournaments. , and demand the best equipment available. The use of the hands, as well as the types of dangers and injuries are different from other martial arts. The metal swords that are used generate serious impact, which the current protection often can't absorb [3]. The ProGauntlet appears to solve this problem very effectively, while still allowing great freedom of movement.

Company

CrossGuard was founded in 2013 by Maarten Kamphuis and Youval Kuipers and is based in Delft, the Netherlands.

The founders and most of the employees are (product) designers who have studied at the Delft University of Technology. The reason for designing a glove specifically for the HEMA market, stems from the personal involvement of the founders in this market. The two founders of the company, Youval Kuipers and Maarten Kamphuis, both practice HEMA and noticed that there was a lack of proper hand protection for their sport. About six years ago they set out to develop the ultimate HEMA glove, which has resulted in the current design of the ProGauntlet.

CrossGuard's slogan is "Protection without compromise". They believe that having good hand protection should not come at the expense of maneuverability of the hands. Their purpose is to design the ultimate HEMA glove.

According to CrossGuard the HEMA market is large enough for the company to continue in its current form. However, the company wants to grow and therefore they want to know about the possibilities of expanding their business into other markets.

Competitors in the HEMA market

Product category

Protection against hard impacts from (metal) swords is the primary function of the ProGauntlet, so in this sense it belongs to a product category that can be described as "heavy HEMA gloves". In the market of protective gloves intended for HEMA, CrossGuard has a couple of direct competitors. The most direct competitors are listed on the next page.

Main competitors

SPES: "LOBSTER" HEAVY GLOVES

€170, Available in 4 sizes

- ✓ Cheaper than the ProGauntlet
- ✓ More sizes available
- ✓ Relatively good protection (but less than the ProGauntlet)
- − Can't move the fingers individually
- − Less flexible
- − Mediocre thumb tip protection

SPARRING GLOVE: INFINITY GLOVE

€190, Available in 5 sizes

- ✓ Lighter than the ProGauntlet
- ✓ Cheaper than the ProGauntlet
- ✓ More sizes available
- ✓ Esthetically similar to the ProGauntlet
- − Less flexible
- − Less joints in the finger allows for less movement
- − Much less protective

RED DRAGON: HEMA GLOVES

€79, Available in 2 sizes

- ✓ Much cheaper than the ProGauntlet
- ✓ Lighter than the ProGauntlet
- ✓ Grippy and durable Leather palm
- ✓ Versatile
- − Much less protective
- − No joints in the fingers, stiff

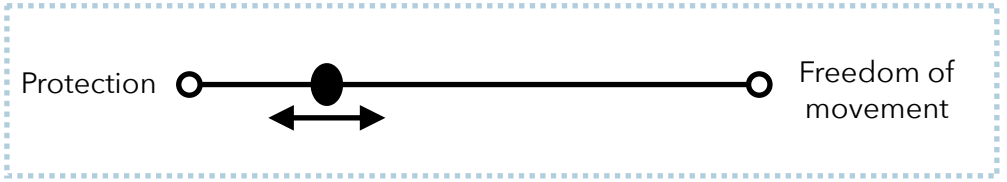
DARKSWORD ARMORY: HEMA GAUNTLETS

$325,Available in one size

- ✓ Steel shell
- ✓ Interchangeable inner glove
- ✓ Grippy and durable Leather palm
- − Can't move the fingers individually
- − Bulky
- − One size
- − Expensive for a simple design

Competition axis

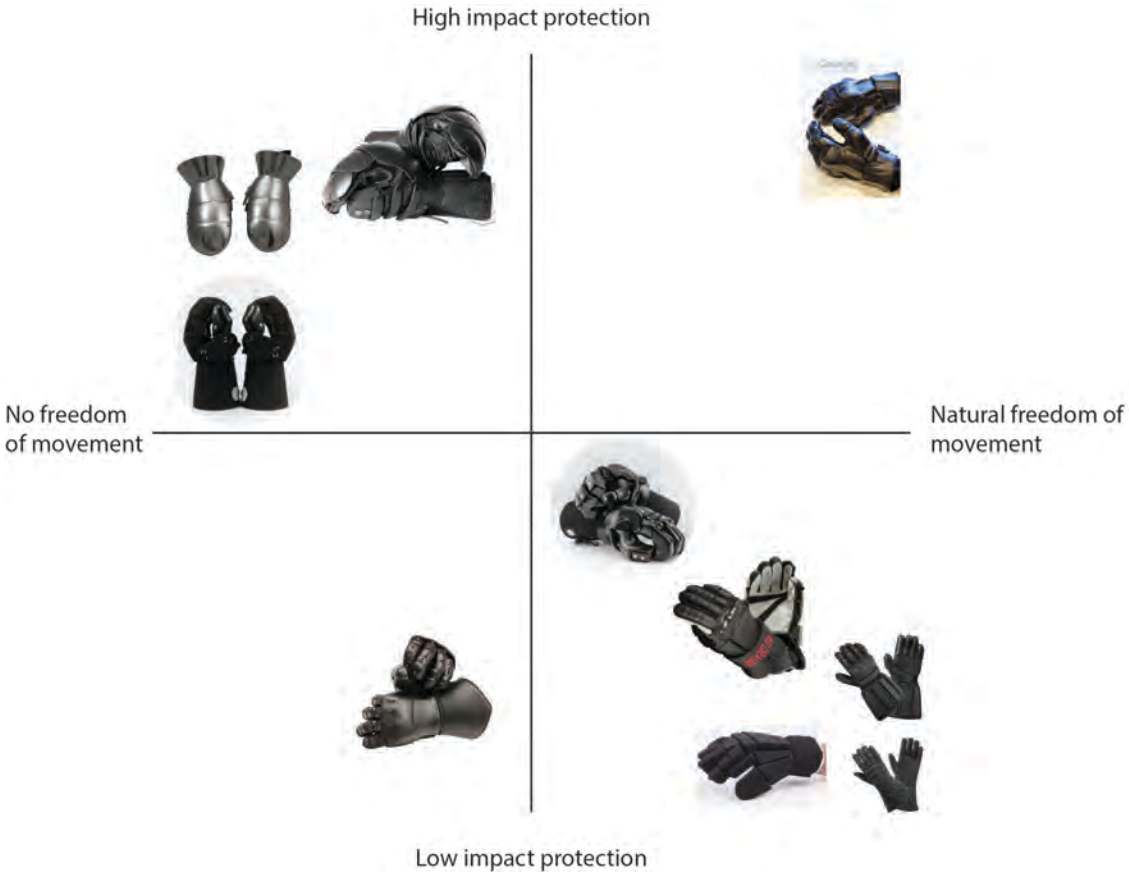
Among HEMA gloves (and arguably other types of protection too), the user usually needs to choose between protection or freedom of movement, as if it's a linear range. Most gloves focus on providing a balance between the two, which often favors one side of the scale.



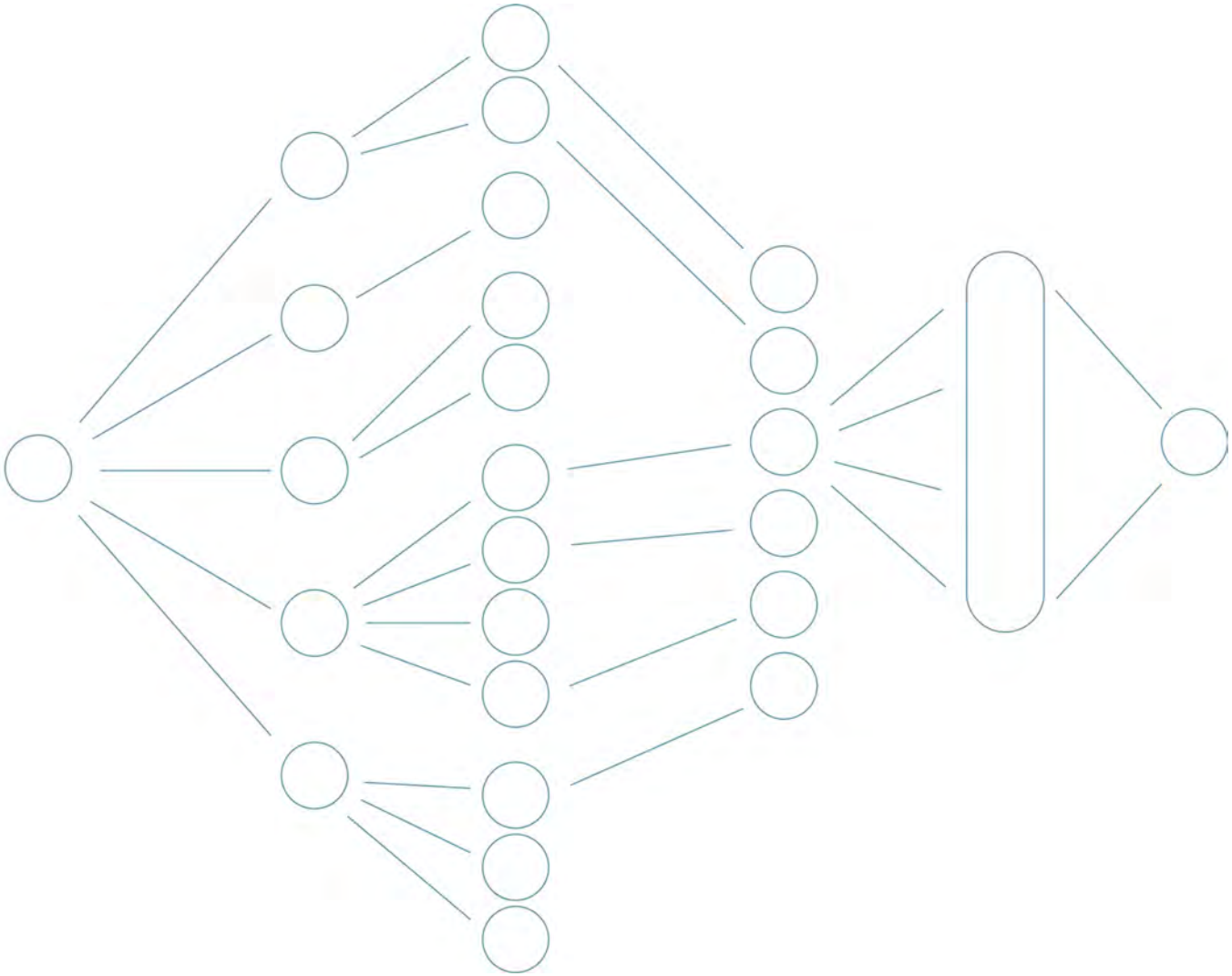
PROTECTION WITHOUT COMPROMISE

The current slogan of the ProGauntlet is "protection without compromise". This refers to the combination of superior protection and a natural freedom of movement. Up until now, users have had to choose between one of the two or by making a compromise between the two. The SPES Lobster Heavy Gloves appear to be the closest competitor of the ProGauntlet in terms of protection, but the freedom of movement is greatly limited when wearing these gloves.

When comparing the ProGauntlet to its competitors in the HEMA market, the ProGauntlet differentiates itself based on the bipolarity [4] of high impact protection and natural freedom of movement. This is illustrated in the competition axis:



3. Method



Research overview

The ProGauntlet may be of great value for users in different markets who need a protective exoskeleton around their hands. At this moment however, it isn't clear in which market(s) this would be the case, if at all. Finding a market of which the (latent) needs meet the characteristics that the glove has to offer will be the main focus of this research, in order to design a market development strategy [5]. In the event that market development alone isn't a viable option for CrossGuard, a diversification strategy will be explored [5].

Determining the next attractive market for the ProGauntlet is done in a number of steps and iterations, which roughly follow the "double diamond" model of diverging an converging. This report consists of a number of sections to guide the reader through this process.

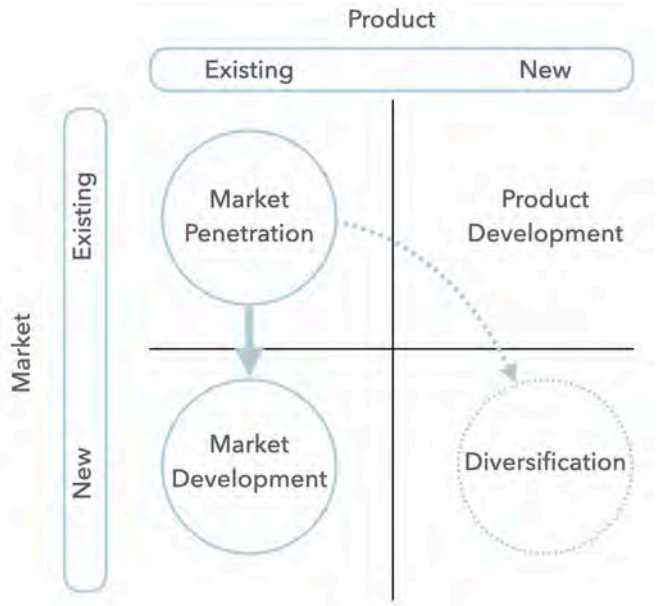
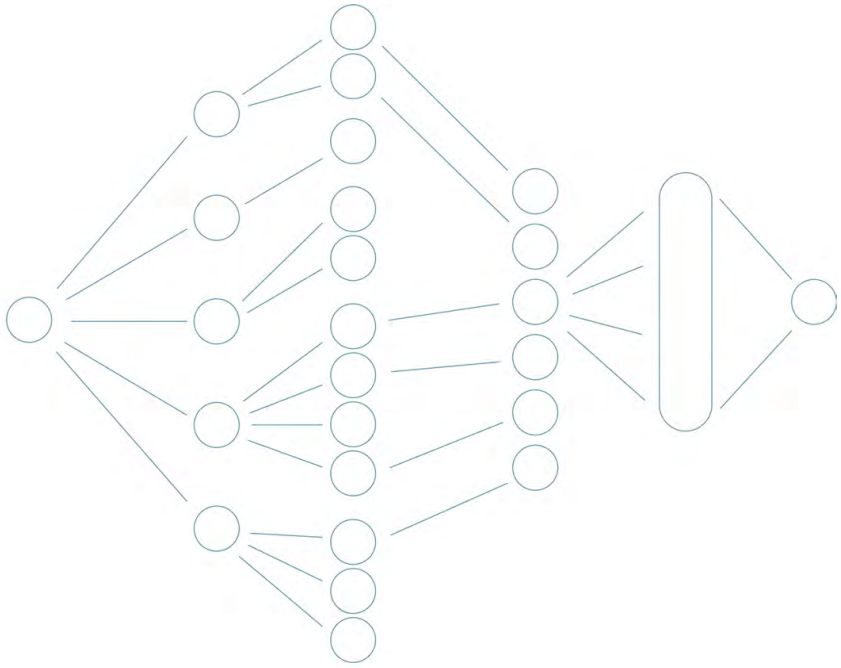


Figure: Ansoff growth matrix

Firstly, the product is analyzed from multiple facets, such as the functional qualities, the appearance, the context and the current competitors. This is followed by an exploration of possible markets, of which the main goal is to make an initial selection of potentially attractive markets for the ProGauntlet. This is done by analyzing the current causes and types of hand injuries and current solutions if applicable. This process involves both diverging and converging. First, a general overview should be made of hand injuries in general, in order to define and subsequently zoom in on the activities of interest. The most promising markets are investigated further through user research.

Based on the findings in these phases, the next markets for the ProGauntlet are determined, and strategies for entering these markets are discussed.



Product analysis

Firstly, the product is analyzed from multiple facets, such as the functional qualities, the appearance, the context and the current competitors. Knowing what the product can do and what makes it special is essential to define the search areas for further research.

- Physical/technical
- Usability
- Strengths and weaknesses

Defining search areas

When finding the next market for a product, if any, it is of great importance to keep the scope of the research wide, but to discard unlikely markets as quickly as possible. A narrow scope can lead to missed opportunities, but staying on a very broad level for too long can lead to a loss of valuable time and a lack of a detailed understanding of the most relevant directions.

Market exploration

Within the search areas, an initial selection of promising markets is made, which are explored further. The main goal of the exploration is to make an initial selection of potentially attractive markets for the ProGauntlet. This is done by analyzing the current causes and types of hand injuries and current solutions if applicable. This process involves both diverging and converging. First, a general overview should be made of hand injuries in general, in order to define and subsequently zoom in on the activities of interest.

Literature research

The ProGauntlet has been designed to prevent hand injuries during HEMA. Since injury prevention is the most important quality of the ProGauntlet, it makes sense to analyze in which other situations hand injuries occur and to assess whether the ProGauntlet might prevent these effectively.

Statistics on subjects such as hand injuries are a good starting point for further research, but statistics alone don't give the full image of a certain context. The potential usefulness and value of the ProGauntlet is dependent on many more factors. Some of these factors can be evaluated through literature research, but user research and testing are also essential factors in assessing the viability of the ProGauntlet a different market. How the glove might be used in practice, what people like about it and what should be changed (if necessary) are examples of factors that can't be judged from literature research alone.

The main goal of this literature section is to make an initial selection of potentially attractive markets for the ProGauntlet, by analyzing the current causes and types of hand injuries and current solutions if applicable. This process involves both diverging and converging. First, a general overview should be made of hand injuries in general, in order to define and subsequently zoom in on the activities of interest.

CAUSES OF HAND INJURIES

When looking for the next potential markets for the ProGauntlet, it is important to determine in which situations the glove can have a positive impact. One way to uncover these situations is to analyze common causes of hand injuries.

COMMON TYPES OF HAND INJURIES

The ProGauntlet mainly protects the outside of the hand against blunt impact. Therefore it makes sense to search for activities that feature this risk.

SEARCH AREAS

- Common causes of (traumatic) hand injuries
- Activities that have a risk of blunt impacts on the back of the hand and fingers
- Activities during which the hands are likely to be exposed to danger

User research

The main purpose of the user research is to find out if the ProGauntlet can be useful for the market in question in any way. Finding the positive elements and opportunities is equally important as defining dealbreakers for the ProGauntlet in the given context.

ABDUCTIVE REASONING

The user research is done through the principle of abductive reasoning. Abductive reasoning is different from inductive and deductive reasoning. In abductive reasoning the starting point is an observation, and the goal is to find the most likely explanation for this phenomenon [6]. In this it differs from deductive reasoning: the aim of the process is to produce plausible conclusions, rather than proving something with absolute accuracy. This approach is useful In qualitative studies like this project – with complex situations that are context-specific – as many findings in the user research are impossible (and often pointless) to prove with complete certainty (deduction). It is also more useful than inductive reasoning in this situation. Inductive reasoning only takes the observable data into account, which makes it less likely to arrive at new, surprising theories.

Interviews

The goal of the user research is to get a good understanding of each context. This is done mainly through semi-structured open-ended interviews with consumers in the selected markets.

Interview guide

The purpose of the interview is to find out:

- How the hands are used
  - What's important in terms of protection and usability
- What the current protection does well and/or lacks
- If protection influences risk-taking behavior or other aspects of the activity
  - If risk-taking behavior is important for performance
- The first impression of the ProGauntlet
  - If the ProGauntlet be useful at all (as a whole or certain elements)
  - General price range that they would be willing to pay

All interview guides are found in the additional appendix report.

Sampling

Finding respondents has mainly happened through a combination of referrals through social connections and by contacting key members of certain sporting clubs. This network-driven sampling is perhaps a type of opportunistic sampling, but in some cases the respondents were also key informants.

TIME-LOCATION SAMPLING

For initial, informal conversations to get a general idea of the context, time-location sampling was used [7], for example by visiting a lacrosse training and talking to the players that were present at that moment. The moment was purposefully chosen to ensure that a large number of players were present and available.

OPPORTUNISTIC SAMPLING

In the Netherlands, field hockey is one of the largest sports, which makes it one of the most accessible markets for user research. The great number of hockey players and clubs makes it easy to contact players directly. Therefore choosing to contact hockey players as a first step during the user research can be seen as a type of opportunistic sampling.

KEY INFORMANTS

The participants of the FMA interviews had contacted CrossGuard themselves, stating that they were interested in the glove. They are high-ranking members in a teaching system that appears to be somewhat popular in the USA: the so-called Atienza kali. This group has many subdivisions throughout the USA, with hundreds of members according to them. As these people have a great knowledge of the context and also have influence on the rest of the population, these can be classified as key informants [7].

In the sampling process, it is important to look at the demographics of the given activity. The dynamics of the market in question can have a great role in shaping the answers of the participant. For instance, the majority of all ice hockey and lacrosse players in the world are located in the USA and in Canada. For these markets it is therefore important to interview players from (one of) these countries, since these countries likely have a guiding role for the rest of the population.

In the case of ice hockey and lacrosse, which both are barely even practiced in the Netherlands, it should be taken into account that the dutch population is probably not representative for the worldwide population in these sports. This could create a skewed impression, since the dutch population in these sports likely follows the American and Canadian populations. Therefore it is important to interview at least one other experienced player from a country where these sports are more common.

Analysis

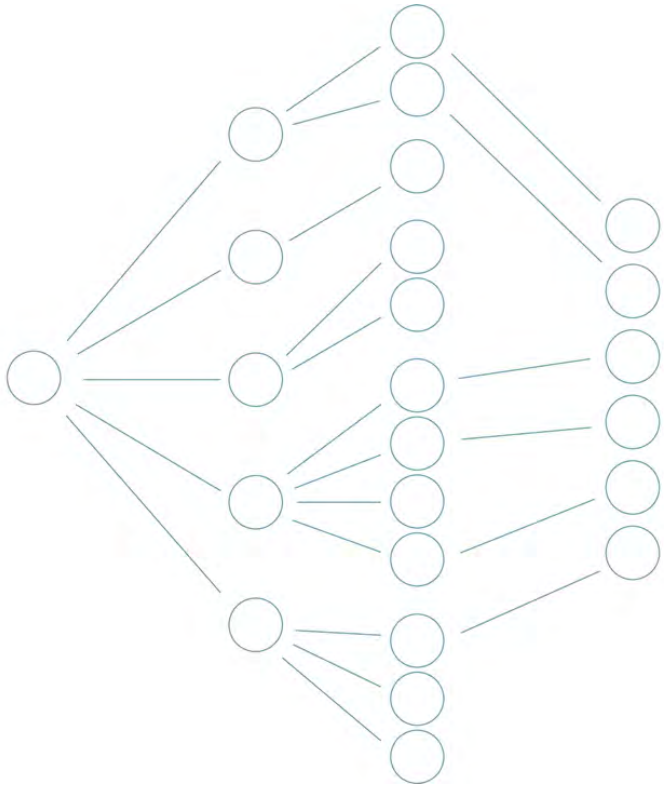
All interviews are recorded and transcribed. These transcriptions are coded and analyzed.

Strategy development

Based on the findings in these phases, the next markets for the ProGauntlet are determined, and strategies for entering these markets are discussed.

- 4C analysis
- Developing a brand identity

4. Results of the market exploration



Product analysis

The ProGauntlet is a unique product in the sense that there are no other gloves that have the same properties of impact protection with a hard outer shell, full articulation of all joints and a light weight at the same time. This uniqueness makes it a very interesting product, but it also makes it challenging to find the right purpose for this product.

Construction

The ProGauntlet consists of two main sub-assemblies. These are the outer shell and the inner glove. The outer shell is made out of many different overlapping scales, which are made out of a specific type of polyurethane (PU) that is extremely tough and strong. This is one of the main elements that makes the glove so impact-resistant. The inner glove is made out of a combination of synthetic leather, mesh and rubber pads to absorb impacts.

Image credit: CrossGuard

Production

The outer shell components are produced in-house, at their facility in Delft. CrossGuard has developed their own special production process, which gives the shell unrivaled material properties.

The inner glove is produced by a third party. Everything is connected by straps and a couple of tiny screws, and the assembly currently also happens in Delft. At this moment, CrossGuard controls every part of the production process themselves, except for the inner glove.

CrossGuard has around 700 pre-orders at the moment of writing, of which the first 30 commercial pairs have been produced. The final design is still being tested on durability, while the production process is being optimized at the same time. CrossGuard aims to produce a few hundred pairs of gloves per month once the production is up and running, which is likely around April 2021.

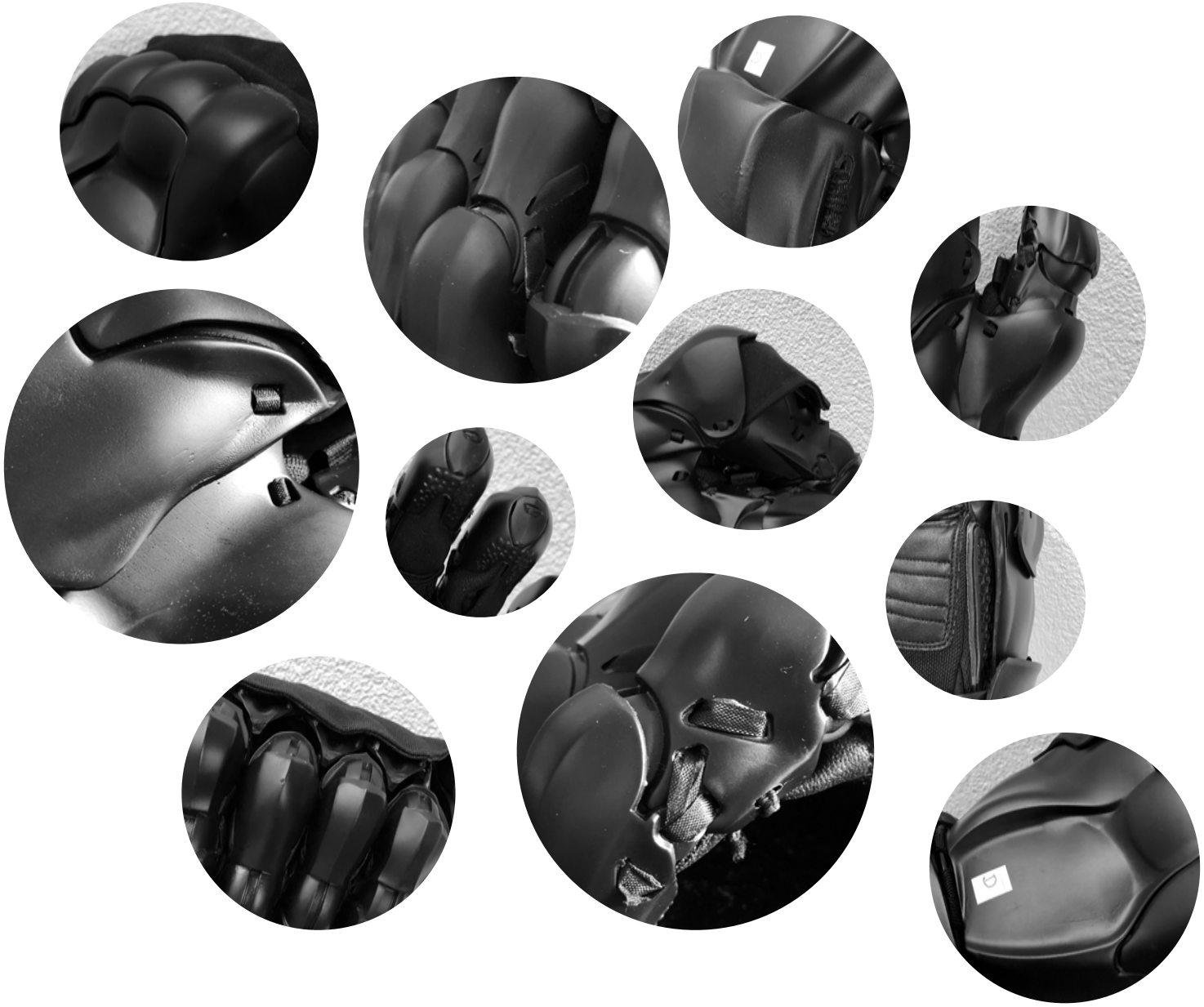
Lifespan

The reactions of the first actual users of the ProGauntlet are highly positive. The enthusiasm with which the ProGauntlet is received in the HEMA community indicates that CrossGuard will be able to sell a substantial amount of gloves in this market.

The average lifespan of a pair of ProGauntlets is not known yet, as the durability tests are still in progress and the actual durability will become clear when the first batch is in use. CrossGuard is also continuously updating the design to improve durability.

Price

The retail price of the ProGauntlet is currently €450. This is necessary to cover the costs of the company and to become profitable. CrossGuard is working on the optimization of the design and the production process of the glove, in order to lower the cost price of each pair.



Esthetics

- The overall design of the ProGauntlet is mainly based on functionality, but the appearance of the glove is also optimized to fit in the HEMA context. It resembles a medieval combat glove thanks to features such as the overlapping scales, the ridges on the back of the fingers, the "veins" on the back of the hand and the emphasized knuckle guard. The black color, matte finish and the somewhat rounded, organic shapes also make it look a but like something from the future instead.

- Right now the ProGauntlet is only produced in matte black, but it would be possible to produce the shell parts in other color. This would increase the production costs, so CrossGuard prefers to keep it like it is.

- The matte finish of the outer shell has been an esthetic choice that CrossGuard has made. The casting process of the polyurethane has been designed in such a way that the parts have a matte finish straight out of the mold. A glossy finish would also be possible, but that would require an additional set of molds, which requires a large investment. Therefore it would be preferable if the finish of the outer shell would remain matte.

Unique design features of the ProGauntlet

The value of the glove can be attributed to a number of technical features of the glove, but these are only the manifestations of the underlying factors that truly set it apart. The most important technical elements are shown on the right.

These three elements, together with many other design elements found in the glove, create a glove that offers an unrivaled combination of impact protection and freedom of movement.

THE SHELL MATERIAL

- The polyurethane (PU) that is used for the outer shell is extremely tough, strong and elastic at the same time. Upon a full-on impact by for instance a steel sword, the material disperses the energy, protecting the hand underneath from harm. Even with such extreme impacts, the material stays intact and simply bounces back to its original shape.

THE ARTICULATION OF THE OUTER SHELL

- The glove allows full articulation of the fingers and joints through a set of overlapping panels. This geometry also improves the toughness and impact protection of the glove.

CONNECTIONS BETWEEN THE SHELL PARTS

- All individual parts are connected with highly durable straps. This allows for a much lower profile and makes the glove lighter, more flexible and more resistant to impact from different directions. Especially the connections in the finger joints are what makes the glove stand out in terms of lightness, mobility and protection.

Using the ProGauntlet

The ProGauntlet is unlike any other glove. Its design is highly optimized for use in HEMA. In the process of finding other applications for the glove, it is important to understand the strengths and weaknesses of it in terms of protection and usability.

As there are only a very limited number of users at this moment, auto-ethnographic is an important method for getting an initial understanding of the real-life properties of the gloves. Wearing and using the ProGauntlet in a wide variety of contexts has given some insights into the strengths and weaknesses of the product, many of which weren't anticipated.

Strengths

EXTREME IMPACT PROTECTION

- The level of protection is extremely high. The fact that the product demos have become an instant classic both within and outside the HEMA world says enough.
  - During this demo, one person puts his hand on the table (of course while wearing the ProGauntlet) and lets another person hit his hand as hard as possible with a double-handed steel sword. This is done many times over, without any pain or injuries.
  - During a demo for hockey players, a hockey stick was even damaged after hitting the glove very hard. The glove and the hand inside were both completely fine.

LONG-LASTING PROTECTION

- The glove is designed to withstand repeated impacts without deforming permanently. As far as this can possibly be tested safely, tests have confirmed that glove still fits comfortably after multiple hard impacts.

TOUGH AND FLEXIBLE SHELL

ABRASION RESISTANCE

- The main purpose of the glove is to protect against hard impacts, but the tough shell is also quite resistant to abrasion. This is beneficial for the lifespan of the product when used in a rough environment.
- The shell also protects against cuts to a certain extent, but it may sustain permanent damage.
  - Cut and puncture tests were done using various sharp objects (hobby knives, screwdrivers etcetera). The toughness of the shell material makes it difficult to make deep cuts, but it is possible.
  - The ultimate test was done by clamping a shell part underneath a circular saw. The saw did create a deep cut, but the material wasn't cut completely through, even after a couple of seconds.
- Although the shell does seem to protect against sharp objects to a certain extent, this is not the main purpose of the glove. In single events, it might save the hand, but then it needs to be replaced afterwards.

FREEDOM OF MOVEMENT

- Although the glove looks quite big and solid, it is very easy to move one's fingers and wrist in any natural way. There is only little resistance and the shell follows the anatomy of the hand very well.

FULL ARTICULATION

- The fingers can be bent completely. This in itself is already impressive for such a glove, but what makes it even better is the fact that there aren't any gaps between the scales of the shell when bending the fingers. This means that the fingers are protected, regardless of their position.

Weaknesses

STRETCHING THE HAND

- It's not possible to stretch the fingers completely. The maximum amount of stretching is just past the resting position of the fingers.
  - When holding something this isn't a problem, but it might create difficulties when picking up things or when resting on flat surfaces.

LIMITED DEXTERITY

- The dexterity is very limited when wearing the glove. Holding large objects is generally not a problem, but picking up small objects or using tools etcetera can be difficult or even impossible.
- The limited dexterity is largely due to the protected finger tips, which impair the sensitivity of the fingers.

HOLDING AND HANDLING OBJECTS

- The fingers are quite thick, so it's easy to get stuck e.g. between the grip of an electric jigsaw or a coffee pot. This can of course be highly dangerous.
- The fingers slide into narrow gaps more easily than they get out, due to the shell structure.

PRESSURE POINTS AND ADJUSTING GRIP

- When holding a stick (such as a hockey stick, lacrosse stick or similar), the glove can cause some pressure points. These make it less comfortable to hold a stick than with your bare hands.

- Holding onto the stick is no problem, but adjusting the grip feels a bit more clumsy than without gloves. This is perhaps something the user can get used to.

WEIGHT

- The ProGauntlet is lightweight for the amount of impact protection that it offers, but its weight (500 grams per glove) cannot be ignored when wearing it.

SIZING

- The ProGauntlet is currently available in one size, which can be described as medium/large for male hands.

- People with smaller hands can wear the gloves, but the purpose of the articulated joints is lost when the fingers don't reach the tip of the gloves and if they don't align with the joints of the shell.

  - To use the glove to its full extent, the range of compatible hand sizes is quite narrow.

HITTING HARD OBJECTS

- If you hit something with a clenched fist while wearing the glove, the finger tips can dislocate from the guiding "rail", which makes it difficult to stretch the fingers again.

Which types of injuries can the ProGauntlet protect against?

BLUNT IMPACT ON THE OUTSIDE OF THE HAND

- As the shell of the ProGauntlet mainly protects the back of the hand, the fingers and part of the wrist against blunt impact, it is useful to look at injuries in these areas. The types of injuries that are mainly caused by blunt impact are fractures and bruises.

- Other injuries such as hyperextension and sprains are less likely to be prevented by the ProGauntlet. Although it will probably offer a certain degree of protection against those other injuries too, it is not designed to prevent them from happening. Therefore this research has mainly been focused on injuries caused by blunt impact.

OUTER SHELL

- The protective outer shell of the ProGauntlet is thickest around the knuckle area, the back of the hand, the base of the thumb and the wrist area. The back, sides and tips of the fingers are also well protected, but the shell is thinner around these areas. The inside of the hand is only protected by the thin inner glove. Due to this geometry, the glove is likely to offer the best protection for activities during which the inside of the hand is less exposed to danger, for example when holding a stick, bat or handrail. The glove has been designed to protect the outside of the hand in any position, meaning that it doesn't matter if the hand is open or closed. This is thanks to the overlapping scales of the outer shell.

- The polyurethane outer shell of the ProGauntlet is very tough, meaning that it can withstand many repeated impacts without losing its material properties or permanently deforming.

FRONTAL STABS BETWEEN THE FINGERS

- One of the standout features of the glove are the extra guards between the fingers. These are designed to protect the user against stabs from a sword.

For who/what is the ProGauntlet useful?

The combination of high impact protection, great freedom of movement and limited dexterity places the ProGauntlet in an unusual segment when it comes to hand protection. In many scenarios that require protection and freedom of movement, dexterity is also needed.

Some indications for the type of situations in which the ProGauntlet can be useful:

- ✓ Repeated, high-impact blows
- ✓ Only the outside of the hand and fingers are protected by the shell, so the palm should be less exposed to danger.
- ✓ Unpredictable impact pattern: the hand must be protected in every position
- ✓ Only impacts; no crushing. The material can be deformed with your bare hands quite easily, so it won't protect against crushing forces whatsoever.
- ✓ The shell will protect against cuts from sharp objects to some extent, but these can permanently damage the glove.
- ✓ Activities that require freedom of movement is needed, but where dexterity is less important
- ✓ Temperature of the environment should be between -30 and +110 °C
- ✓ Likely a setting in which the use of gloves is already normal
- ✓ Users should be willing to pay a substantial amount of money for protection

Research directions

Unfortunately, the ProGauntlet cannot prevent all types and causes of hand injuries. It is important to separate the scenarios in which the ProGauntlet can be useful from those in which it won't as quickly as possible.

For instance, despite the fact that according to one study, a quarter of all hand injuries happen after the consumption of alcohol [8], It can be assumed that the ProGauntlet won't prevent any of these injuries from occurring, unless users would wear the ProGauntlet to bars and such (which would potentially open up a whole other set of problems). Therefore such injuries will not be further investigated in this report, as well as other types and causes of injuries that the ProGauntlet will not help in preventing from happening.

The research categories in this stage of the project are based on a combination of the reviewed literature about hand injuries, as well as suggestions from the people at CrossGuard, interested (potential) consumers, brainstorm sessions and personal stories of people who have experienced hand injuries. This has led to the following research categories:

RESEARCH CATEGORIES

1. Armed martial arts
2. Occupational hand injuries
3. Military and law enforcement
4. High-risk bat-and-stick sports
5. Motor and bike sports

The initial aim of the literature research is to get a general idea of the chances for the ProGauntlet in each of these categories. If the literature suggests that there are unresolved causes of hand injuries in any of these categories, then a further investigation into activities within these categories is done to determine potentially interesting markets.

List of the activities researched during the literature review/market exploration

ARMED MARTIAL ARTS

- Kendo
- Filipino Martial Arts

OCCUPATIONAL HAND INJURIES

- Industry (including construction, oil & gas)

MILITARY AND LAW ENFORCEMENT

- Military
- Law enforcement
- Fire brigade

HIGH-RISK BAT-AND-STICK SPORTS

- Field hockey
- Ice hockey
- Lacrosse
- Cricket

MOTOR & BIKE SPORTS

- Motorcycle riding
- Motocross
- Mountain biking

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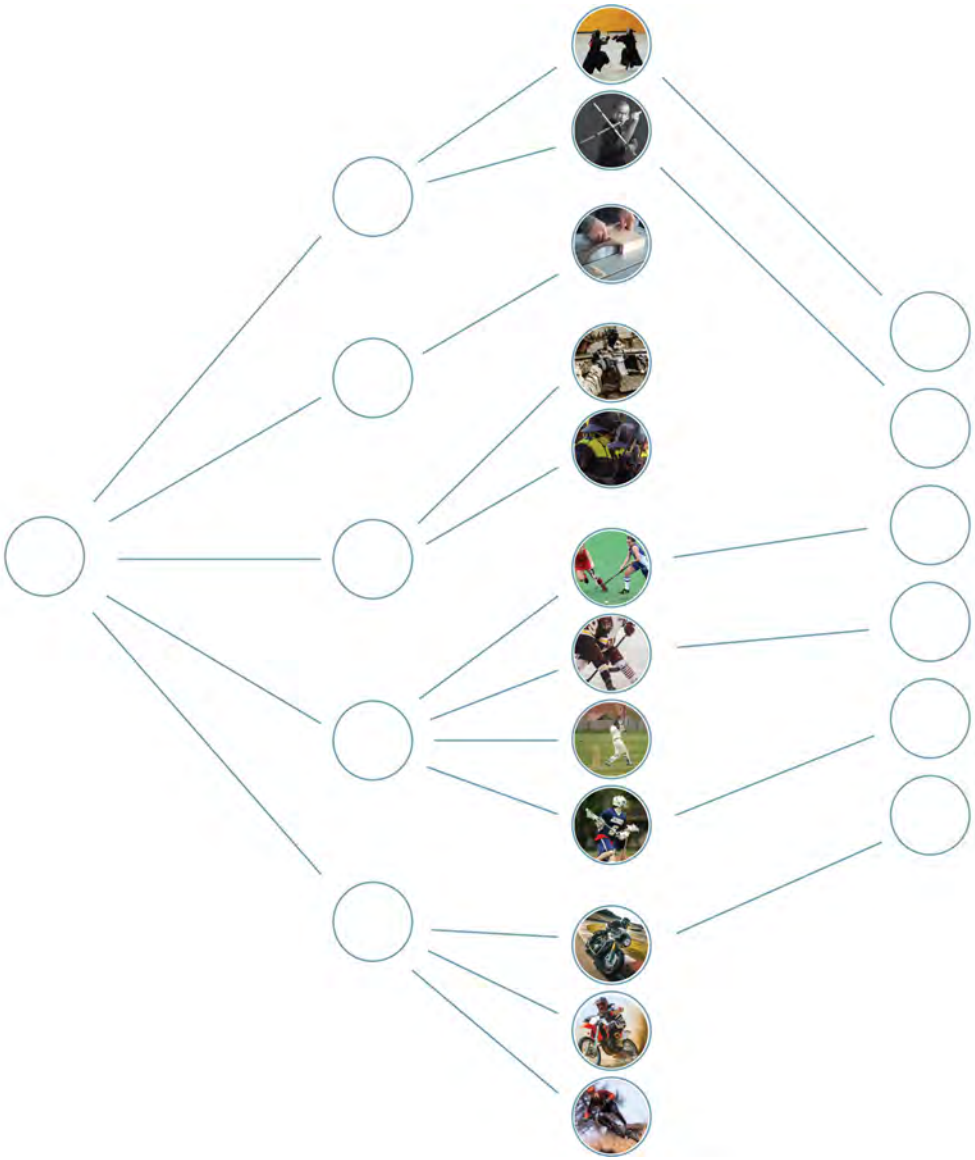


Literature research results

Identifying common causes of hand injuries can be helpful in defining activities where the ProGauntlet can be of value. The incidence, type and causes of hand injuries vary throughout the population, but there are some general trends.

- The estimated proportion of hand injuries varies between different studies, but up to 28% of all injuries are related to the hands [8].

Such numbers suggest that there is a lot of room for improvement.

GENERAL REMARKS

The data is retrieved from a great number of different studies and other sources. In some cases, different studies have vastly different results, which makes it difficult to draw general conclusions. The aim of this section is to give an overview of the results as clearly as possible, and to relate them to the ProGauntlet wherever possible.

The full literature research for each market can be found in appendix 2. As for the user research, the results can be found in appendix 4. The interview transcripts and the codebook are included in the additional appendix report.

Common types of hand injuries

METACARPAL FRACTURES

- The ProGauntlet mainly protects the outside of the hand against blunt impact, which is the main cause of fractured metacarpals [9].

- Two of the most common types of hand injuries are fractured metacarpals and fractured phalanges [10]. Metacarpals are the bones in the back/palm of the hand, and are the largest bones in

the hand. Phalanges are the bones in the fingers: there are three for each finger and two for each thumb.

- Most metacarpal fractures happen among the younger population, between ages 15 and 24. Over three quarters of these metacarpal fractures happen among men, mainly by impact on the fist, while punching a hard object. Sports are the second most common cause, and within this category, contact sports like American football are the main cause of injuries [11, 12].

Occupational hand injuries

The full analysis can be found in appendix 2.

- Almost half of all hand injuries happen at home and about one-fifth happen while at work, but the injuries at work are often more severe [8].
- Generally speaking, most hand injuries occur amongst men under the age of 40, and especially amongst those whose with physically demanding jobs [8, 13].
- Unlike most other injuries, the ratio of hand injuries is not equal between genders. Men sustain over three times as many hand injuries as women [14].

Occupational hand injuries are a serious problem, but the ProGauntlet is unlikely to improve this situation. Put simply, the ProGauntlet isn't designed for industrial use. It isn't designed with handling objects and doing manual work in mind, and more importantly lacks the fingertip precision to do this. Most importantly perhaps, the ProGauntlet also won't protect against some of the most common types and causes of occupational injuries very effectively.

The ProGauntlet is designed to offer maximum impact protection against impacts, but impact protection doesn't appear to be the most important feature for industrial gloves. The impact protection of the ProGauntlet comes at the expense of many other features that are considered standard for industrial gloves.

The technology behind the articulated impact protection of the ProGauntlet could perhaps be useful if it would be translated to a completely different design that incorporates those other essential features of safety gloves. The project brief, however, states that CrossGuard wants a minimum amount of changes to the design of the ProGauntlet, preferably none at all. In its current shape, the ProGauntlet is highly unlikely to be usable in industrial settings.

Hand injuries in sports

The full analysis can be found in appendix 2.

- Sports are a common cause of hand injuries, accounting for 10% to 25% of these injures [10, 15].
- Up to 25% of all sports injuries are related to the hand and wrist, and increased sports participation rates have led to a rise in the number of injuries in recent years [15].
- The injury trends for most sports appear to be stable. This suggests that there is room for structural improvements in the prevention of hand and wrist injuries during sports [16].

IMPACT-RELATED HAND INJURIES

- As the ProGauntlet mainly protects against impact-related injuries, these form the main area of interest during this research.

- Impact-related hand and wrist injuries are most commonly seen in contact sports, for instance ice hockey, basketball, American football, rugby and lacrosse [11, 15].

- Such contact sports are common causes of metacarpal and phalangeal fractures. These fractures account for up to 10% of all fractures during sports [15]. Most of these fractures appear to be caused by direct blows or other impacts. Impact from a bat or stick and falling with a closed fist are named as common causes [11, 17].

Sports injury prevention with the ProGauntlet

Preventing hand injuries in sports altogether would of course be great, but the ProGauntlet cannot protect against every type of danger. Therefore, only certain types of sports injuries are relevant during this research. The ProGauntlet specifically protects the outside of the hand against (repeated) impact.

Limitations of the glove in sports

When wearing the gloves, the freedom of movement is almost unrestricted, but the sheer size and bulkiness of the glove makes it difficult to handle objects with the fingertips. The sports that are interesting for CrossGuard should have an injury profile that shows a significant amount of overlap with the protective qualities of the ProGauntlet. The ProGauntlet should help to prevent common injuries without being a burden to the athletes.

The dexterity and fingertip sensitivity are greatly limited while wearing the ProGauntlet, so the current design of the glove is not useful for activities that require these qualities.

For this reason, sports like basketball and American football aren't investigated, despite the relatively high number of hand and finger injuries. In these sports, nobody uses hand protection, let alone a big glove like the ProGauntlet. The glove is too unwieldy and will definitely interfere with the players' performance. Similarly, during soccer none of the players wear hand protection, except for the goal keeper. These gloves are mainly designed to have stiff fingers with a large surface area to block more balls and a durable and grippy palm to grab the ball. The need for protection is quite minimal. These properties don't align with what the ProGauntlet offers. Besides this, it is a highly conservative sport. Innovations such as the Video Assistant Referee took years to implement due to criticism from many stakeholders.

High-risk bat-and-stick sports

- The overall incidence of hand and wrist injuries is relatively high in bat-or-stick sports such as field hockey, ice hockey, lacrosse and cricket [18]. During bat-or-stick sports, the players usually hold the bat or stick in their hands for most of the game. This appears to align with the intended use of the ProGauntlet (holding a sword) to at least some extent.

- The exact hand injury statistics for these bat-or-stick sports often differ per study, so it is sometimes difficult to compare the results. Despite this discrepancy in results, a couple of sports can be identified as a recurring theme in multiple studies. These sports are: **field hockey, ice hockey, lacrosse and cricket**.

RISKS IN BAT-OR-STICK SPORTS

- In the aforementioned sports: field hockey, ice hockey, lacrosse and cricket, the ball or puck forms one of the greatest risks. The high velocity of this hard ball or puck forms one of the main injury risks, especially without wearing gloves [18].

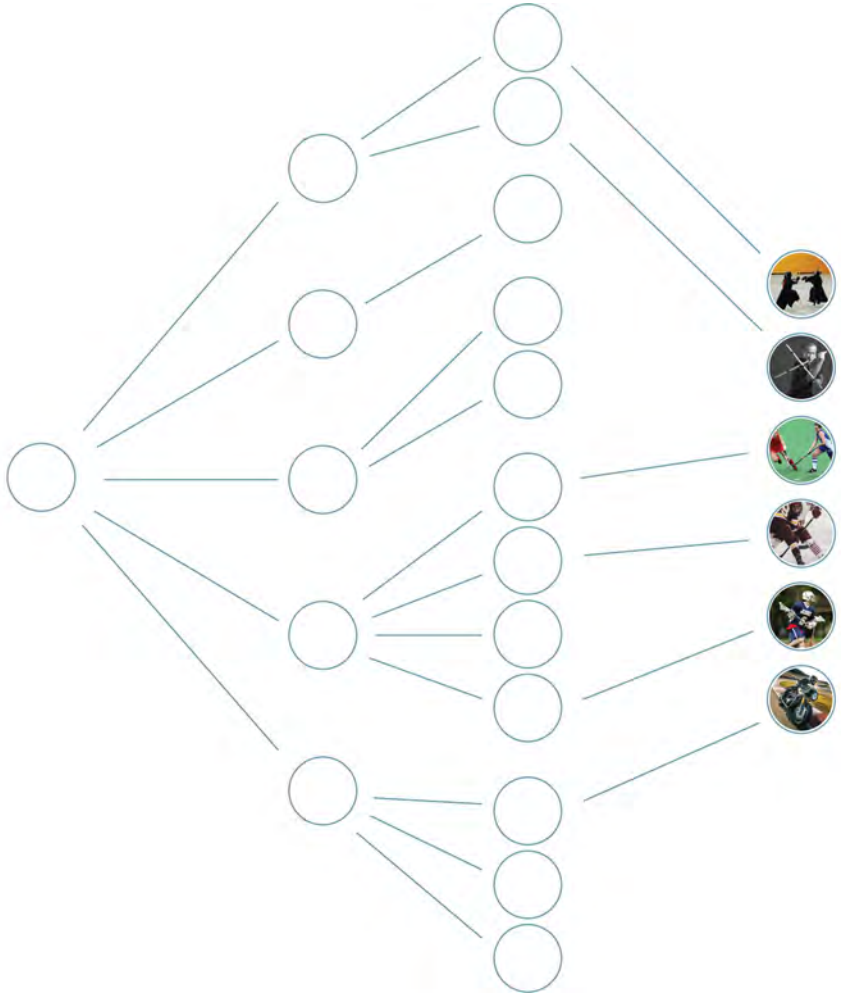
- The amount of metacarpal, finger and thumb injuries appears to be significantly higher among ungloved field hockey players, compared to gloved athletes in ice hockey and lacrosse [11, 19]. This may indicate that gloves have a positive effect in terms of injury prevention. That said, hand injuries appear to be relatively common in all of these sports, but the most common in field hockey.

User research results

Based on the exploration of different potential markets, regarding hand injuries; causes, incidence, types, current measures, the most interesting markets (in which the ProGauntlet might be useful) are selected. These markets are:

- Kendo
- Filipino martial arts
- Field hockey
- Ice hockey
- Lacrosse
- Motorcycle riding

Interviews have been conducted within these six markets, in order to find out if the ProGauntlet can be useful in practice.



Interviews

Semi-structured open-ended interviews

It total, ten semi-structured open-ended interviews have been conducted. The interviews varied in duration, depending on the length and depth of the answers of the participants. The length of the interviews ranged between 40 and 80 minutes.

The interviews were all conducted in the native language of the participants, to ensure that they could express their thoughts clearly and without a language barrier. Six of the ten interviews were conducted in Dutch and four were in English. The interviews have been done via Zoom, due to large geographical separation, and due to Covid-19 measures in some cases.

Activity	No. Of interviews done	Country of residence of participants
Kendo	1	Canada
FMA	2	USA
Field Hockey	3	The Netherlands
Ice Hockey	2	USA & The Netherlands
Lacrosse	1	USA
Motorcycle riding	1	The Netherlands

Informal interviews

In addition to the semi-structured open-ended interviews, informal interviews have also been conducted with users in various markets, to gain a better understanding of the context. The insights from these interviews aren't included in the coding, but they are included in the findings of the user research, in the appendix.

Analyzing the results

Transcribing

All ten interviews were recorded and transcribed. The full transcripts are found in the additional appendix report.

Most of the interviews were transcribed (almost) in verbatim, to preserve the richness of the data. Some filler words were left out to make the transcripts more readable so this would be called "intelligent verbatim". As this method of transcribing is very time consuming, some parts of a couple of interviews were transcribed non-verbatim, with only the answers of the participants, phrased without unnecessary words.

Coding

For the coding of the interview transcripts, some of the coding methods as defined by Saldaña [20] were used. During the first round of coding, multiple coding methods have been used. Since a lot of the relevant data has to do with (inter)actions, process coding has been used primarily. Other types of coding include holistic coding, versus coding and in some instances also in vivo coding. In this research, it is essential to distinguish the priorities of the users, and to discover which trade-offs they are willing to make, for

example protection vs. freedom of movement. Versus coding is very useful for this.

The coding of all interviews has produced **285 different codes, divided into 32 groups**. The full description of these can be found in the codebook in the additional appendix report.

Interpreting the codes and code groups

Due to the large difference between the types of activities and the variation in length and number of interviews, it is difficult to draw general conclusions for the study as a whole just by looking at the codes and code groups. Just looking at the number of codes per group and the number of instances in which codes are used, is likely to create a distorted view.

For example, only one in-depth interview has been done for lacrosse, but this did take around one and half hours and was very comprehensive. This might produce less codes than the three interviews that have been done for field hockey, but that doesn't mean that there are less problems in lacrosse hand protection.

The findings vary greatly between the different activities. This was to be expected, given the great variation in activity type.

The main purpose of the interviews is to find out if the ProGauntlet can be useful in any way. Although the codes and code groups are useful tools to organize and structure the findings, the richness of the data is often lost in the process. During the process, some of the most valuable insights were gained by going back into the actual data of the interviews. In finding possible solutions for such dealbreakers. The full analyses of the interviews, including many of the original quotations, are found in the additional appendix report.

Summary of findings per market

This is a summary of the combined findings from the literature research and, if applicable, user research. This is intended to give a quick overview of the most important findings. **It is important to note that these results assume an unchanged or minimally changed design of the ProGauntlet.** Design changes are discussed later on in this report.

Armed martial arts

KENDO: NO

- The protection of the ProGauntlet does not align with the needs in kendo. It has a lot of protection in irrelevant areas, but is missing the most important part: The extended wrist protection.
- The hand movements and strikes done during kendo are very different from HEMA. The movements are much simpler and mainly require wrist mobility. The ProGauntlet is too limiting in the wrist mobility and "too complex" in the fingers.
- The sport is rooted in longstanding traditions. Most practitioners specifically chose for kendo partially for this reason and aren't likely to accept a new type of protection.

FILIPINO MARTIAL ARTS: YES*

- * Only a tiny niche of the FMA market, where people engage in full-contact combat with metal blades. This group is called Atienza Kali and consists of about 500 people, most of whom live in the USA.
- In other types of FMA people usually don't use hand protection at all or just very lightly padded gloves. They have no interest in the ProGauntlet or a similar gloves, as the glove will likely cause

injuries during unarmed combat and limits the precision in the fingertips.

Occupational hand injuries

INDUSTRY (INCLUDING CONSTRUCTION, OIL & GAS): NO

- Cuts and punctures are leading causes of occupational hand injuries. The ProGauntlet is not designed to withstand these. The shell might offer some (single-use) protection, but other solutions exist that are better at preventing these.
- Impact protection isn't the most important quality of an industrial glove. The ProGauntlet has plenty, but it comes at the expense of essential qualities such as dexterity and cutting resistance.
- Industrial gloves have various certifications for different types of hazards. The ProGauntlet will most likely easily pass the highest standard of impact protection, but the other certifications will likely be lacking.
- The violation of safety protocols and other human errors are the most important causes of occupational hand injuries. Wearing the ProGauntlet won't change much about this. If anything, the lack of dexterity could even endanger workers or people might take off the glove, rendering it useless.

Military and law enforcement

MILITARY: NO

- Many hand-related activities appear to be comparable to industrial work in terms of needs, which is also reflected in the design of the current gloves. The ProGauntlet can't compete with these in terms of features. If anything, even more dexterity is needed than in industrial settings, which is why many tactical gloves have a thin or exposed index "trigger" finger.

LAW ENFORCEMENT: NO

- Highly similar to the military context, the exact use of the hands during police work is unclear and variable, and dexterity is needed. The ProGauntlet also lacks a lot of standard features in this context.

FIRE BRIGADE: NO

- The maximum operating temperature of the PU shell of the ProGauntlet is 110 degrees Celsius. Above that, it will disintegrate, which produces hazardous fumes. This is too low for use in settings that involve hot environments and fire.

High-risk bat-and-stick sports

FIELD HOCKEY: NO

- At the moment, no. Maybe a heavily stripped-down version, but this will require a complete redesign. The glove is too big, too heavy, too restrictive and too warm. Less protection would still suffice and the glove should lose its bulkiness.
- There are a high number of (serious) hand injuries in field hockey, which can likely be prevented by a ProGauntlet-like glove.

ICE HOCKEY: NO

- Maybe with a redesign but there's no clear need for better hand protection.

LACROSSE: NO

- The ProGauntlet is way too heavy. Lacrosse players need light and nimble gloves. They often give up protection for better performance.
- Injury acceptance and risk taking seem to be a big part of lacrosse, and players don't want to sacrifice performance. A great number of complex hand movements are used during lacrosse, and therefore the weight and freedom of movement of gloves are extremely important. Even more than in the other sports that were researched.
- The thumb protection in the ProGauntlet could be an interesting element for lacrosse gloves, though

CRICKET: NO

- Most hand injuries occur during fielding. Glove use is forbidden during fielding and the ProGauntlet protects the outside of the hand rather than the inside (which is needed during catches).
- The current batting (hitting) gloves seem to give enough protection already.

Motor & bike sports

MOTORCYCLE RIDING: NO

- The ProGauntlet would likely protect against most risks, but its real strength, repeated impact resistance, doesn't really align with the needs of motorcycle riders.
- Dexterity and fingertip feeling are essential qualities of a motorcycle glove. These qualities are currently lacking in the ProGauntlet, and these are definitely dealbreakers.

MOTOCROSS: NO

- In addition to the arguments listed for on-road motorcycle riding, the glove likely won't protect against injuries caused by impacts from the handlebar, which is a leading cause of hand/wrist injuries in motocross. The needs of motocross don't align with the qualities of the ProGauntlet very well.

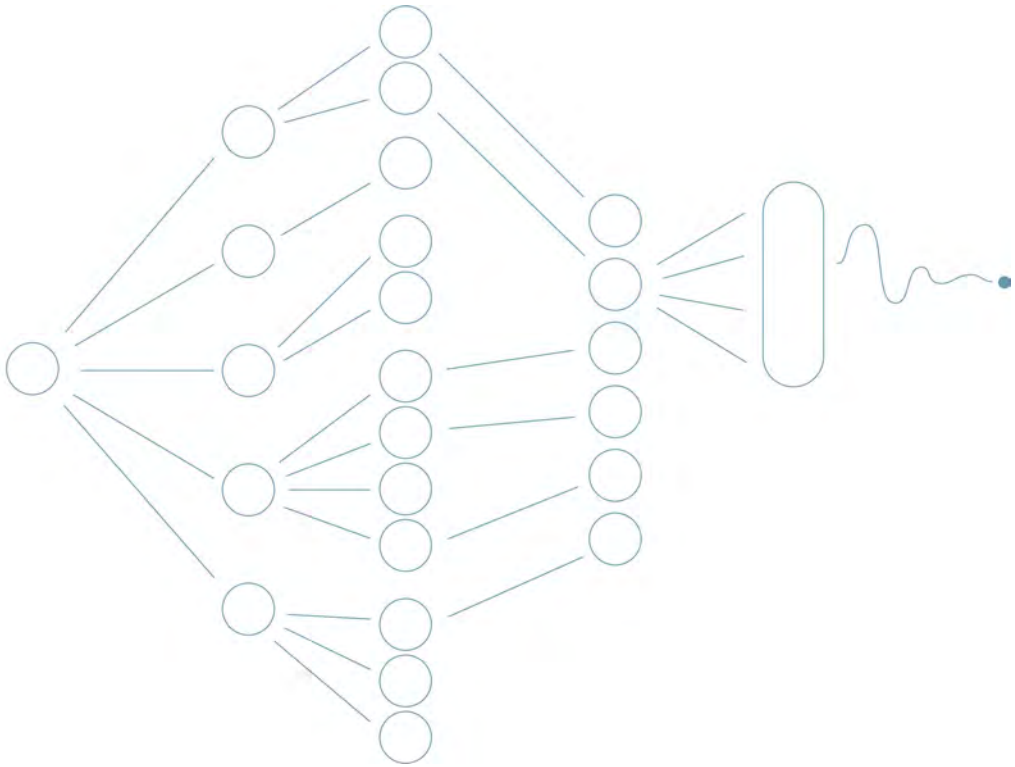
MOUNTAIN BIKING: NO

- The protection that the ProGauntlet offers does not align that well with the needs of mountain bike riders. Besides this, the glove is also much bulkier than anything else on the market and it will likely interfere with the ability to control the brakes and shifters.

Conclusions of the market exploration

Is there a viable follow-up market for the ProGauntlet?

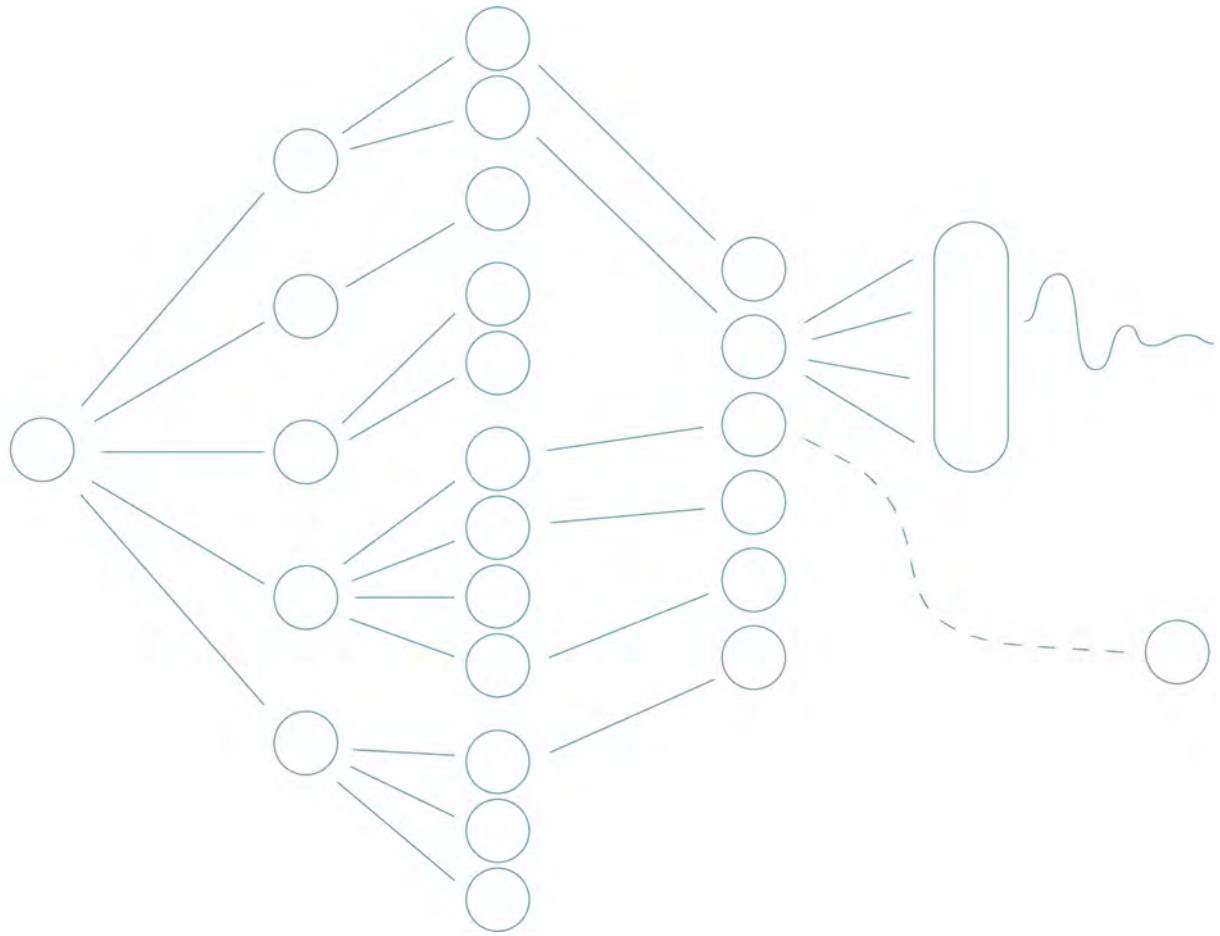
NO



With the ProGauntlet, CrossGuard has developed a glove that can resist repeated extreme impact. The glove is highly optimized for HEMA, but in other use cases, aspects like size and weight are equally important as protection. Of all the markets that were researched, none appears to be a viable market for the ProGauntlet.

The only exception to this is a niche of the Filipino Martial Arts market, where people use metal blades and engage in full-contact combat. This group consists of about 500 people, mostly located in the USA. These people already buy their equipment through the exact same reseller as CrossGuard already has in the USA, so there is no need to change anything in terms of sales channels. This group would be a nice addition to the total market for the ProGauntlet, but it is too small to justify any design adjustments. The full strategy can be found in appendix 5.

5. The next steps



Key points of this chapter

- The design of the ProGauntlet is highly optimized for HEMA. Through its technological advancements it creates a meaningful change in the sport, which is why it is being received so well.
- In other activities, many of the design features of the ProGauntlet don't align with the needs very well. This makes the product much less innovative and less attractive for consumers.
- The ProGauntlet is therefore unlikely to be successful in any other market than HEMA and a tiny niche of the FMA market, where people engage in full-contact combat with metal blades.
- The lack of a viable follow-up market has led to a change in the design brief. CrossGuard has acknowledged that a redesign will be necessary, so from now on the focus be on finding the next market for a redesigned glove.
- The most promising market for a redesign appears to be field hockey.

The next market for the ProGauntlet

One general insight that can be concluded from the user research, is that it has shown that the design of the ProGauntlet is extremely optimized for a highly specific use case, and that it most definitely will need to be redesigned for any other type of use. The use cases for the ProGauntlet are limited to armed martial arts with metal swords. This includes HEMA and a segment of FMA.

Filipino Martial Arts

After concluding the user research, it appears that the only viable market for the ProGauntlet, without redesigning the product, is a certain part of the FMA market.

FMA seemed like an attractive market for the ProGauntlet in earlier research, but after further investigation the market appears to be much smaller than expected. Instead of being representative cases for the whole market, the participants of the interviews seem to be outliers, who practice a type of FMA that is not considered mainstream.

Although there is some level of organization within the FMA population, is is definitely not a widely known, standardized and/or regulated sport. There are (almost) no clear, centralized sources of information on FMA, which likely has to do with the fact that there is no such thing as an "official" type of FMA. This makes it very difficult to navigate through all the information without being part of a group.

Most groups appear to have their own interpretation of the martial art, which creates a large variance in needs among the different groups. Without a central organization, communicating with all different (sub-)groups can be challenging and time-consuming.

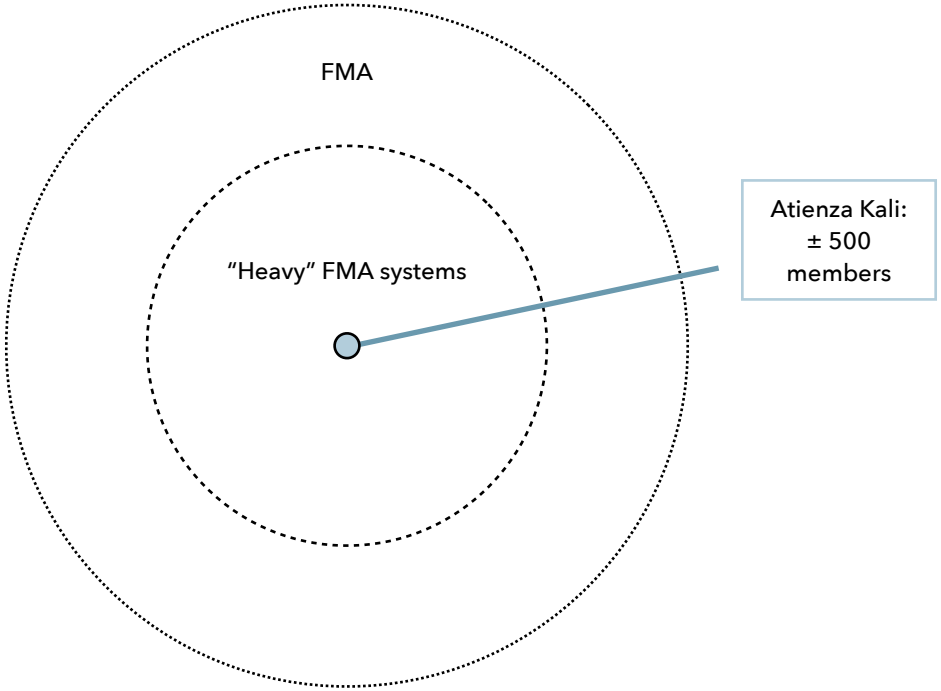
The reported estimations of the global market size don't appear to be a realistic representation of the actual number of people that would be willing to buy the ProGauntlet. Allegedly, there are 10 to 15 thousand FMA practitioners in the USA and "hundreds of thousands" of practitioners worldwide, but the available evidence doesn't suggest that many of these people would be interested in the ProGauntlet.

Based on the research done during this project, it appears that only the so-called Atienza Kali group is really interested in the

ProGauntlet. These people have voiced a strong desire to buy, test and review the ProGauntlet, but other groups and systems apparently don't need such hand protection. Due to the lack of standardization and the variance in techniques and needs of different systems within the FMA market, it seems unlikely that CrossGuard can design a single glove that meets the needs of those different systems all at once.

The members of Atienza Kali are likely the only ones who would actually be willing to buy the ProGauntlet, as they are the only known system that would clearly benefit from it. That comes down to around 500 users, most of whom would be willing to purchase a ProGauntlet.

The members who were interviewed appear to be quite well-connected in the FMA scene in the USA and have also offered to help promoting it within their network. As this seems to be the only other market/niche in which the ProGauntlet can be sold without making any changes to the design, it is highly advisable for CrossGuard to maintain this contact, in order to sell as many pairs of gloves as possible in this niche of the FMA market. The full analysis of this market can be found in appendix 5.



No viable market for the ProGauntlet: now what?

At the start of the project, the objective was to find the next viable market for the ProGauntlet with as little changes to the design as possible. Throughout the process however, it has become clear that it is most likely impossible to introduce the ProGauntlet in any other market than HEMA in its current shape or with minimal design changes. Its highly optimized, HEMA-specific design in combination with a high price tag makes it an unlikely alternative in any other use case.

Redesigning the ProGauntlet

CrossGuard understands this and has changed their attitude towards redesigning the ProGauntlet over the course of the project. Whereas the project brief states: “technical changes in the design should be kept to an absolute minimum, preferably none at all”, a complete redesign is now on the table as a serious option. This changed attitude has been in part due to the research done during this project.

Another reason is that CrossGuard has discovered that redesigning the product requires less resources than they had anticipated at first, so a redesign is now justified if it can give access to a much larger market.

The possibility of a complete redesign (as opposed to minimal changes) might change the outcome of the project, but it does not mean that the work that has been done up until now is irrelevant.

Exploring different markets for the ProGauntlet was a good starting point, as it allowed for a thorough analysis of the different markets, as well as the strengths and weaknesses of the current design. The limitations of this approach were actually helpful in the process.

Instead of determining the next market for the ProGauntlet in its current (or highly similar) shape, the main focus has become to determine the most interesting market in which to introduce a redesign.

Redesign

Key points

- Most of the arguments for discarding certain markets remain relevant.
- A redesign would still have the same basic qualities as the ProGauntlet.

The possibility of introducing a redesigned glove in a different market has a great impact on the process of defining the next market.

Without a redesign, the choice for the next market is straightforward: a certain segment of FMA is the only possible market besides HEMA, based on the research. With a redesign however, the problems within each market should be assessed carefully, to find out where the greatest need for a protective glove exists, and if CrossGuard might be able to fulfill this need.

At the time of the interviews the objective was still to find a new market with minimal changes to the product. Luckily, questions about potential design changes were incorporated in the interview guide, as these were asked to give greater insight into the possibilities and problems within each market. These can be used to find out in which market the needs and type of use align with what an impact-resistant glove similar to the ProGauntlet has to offer.

Features and limitations of a redesign

With or without redesigning the ProGauntlet, the leading principle of introducing a protective glove into a new market remains the same: preventing hand injuries. This is the main purpose of the glove and must not be forgotten.

Despite the fact that a redesign can change the glove drastically, the basic elements that make the ProGauntlet unlike any other glove will (most likely) remain the same to a great extent.

USP's of the ProGauntlet

These elements are:

OVERLAPPING SCALES

A shell structure, consisting of overlapping scales. This is what allows for fluent finger movements, full articulation and protection in every finger position.

POLYURETHANE SHELL (OR A SIMILAR MATERIAL)

A great amount of strength and impact resistance can be attributed to the material of the shell. CrossGuard won't suddenly change to completely different materials, like steel or carbon fiber. If anything, it will be a different polymer that is easier to use for mass production than the current material.

IMPACT PROTECTION

A design that is focused on repeated impact protection. The ProGauntlet is completely optimized to provide proper protection against a specific type of hazard: impact. It protects against extreme impacts repeatedly, without losing its protective qualities over time. Protection against other mechanical and non-mechanical hazards is limited or not applicable. Examples of mechanical hazards are cutting, abrasion and crushing, and non-mechanical hazards are e.g. heat, acids and ionizing radiation. The activity in question needs to match the protective qualities of the (redesigned) ProGauntlet.

Considerations in choosing the next market

If we, instead of looking at the ProGauntlet as a product, look at its underlying qualities, then we can determine in which market such qualities can create a new meaning through innovation. To explain this, it is helpful to look back at the HEMA market: why is the ProGauntlet so special in this market?

Previously discarded markets

Since redesigning the glove entirely would change many of its properties, it could be argued that all markets that were regarded as unlikely in the literature research should be reconsidered, for instance construction. This is not true. The main arguments for disregarding those markets in that stage of the process are still relevant, since the most important features of the glove remain the same.

In industrial settings for instance, the reality still remains that impact related injuries aren't the biggest concern. Almost half of all injuries are cuts and punctures, and the violation of safety protocols is a leading cause of occupational hand injuries. An impact-resistant glove won't change anything about this.

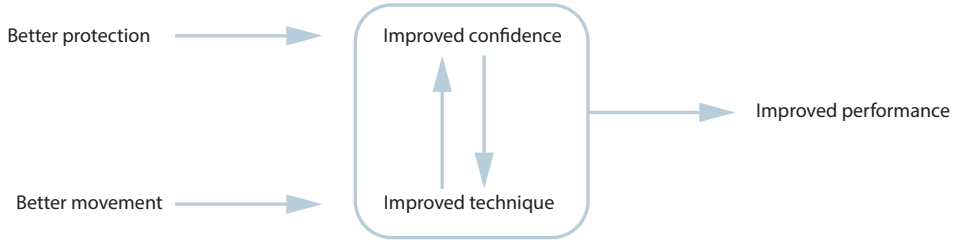
Hand protection in the given market

The current state of hand protection and the historical development of hand protection in the given market are also important factors to consider. For instance, ice hockey gloves have been developed and used for decades already. These iterations have inevitably led to a design that has been optimized in many facets. This can make it more difficult to enter that market, as people have a very clear image and association with ice hockey gloves.

Incremental vs. radical innovation

CrossGuard has essentially introduced a highly optimized, high-tech product into the existing market, that combines the most important qualities of heavy HEMA gloves and light gloves. This leads to a product that is unlike any of the competitors in terms of functionality, design, performance and user experience.

It is likely that the ProGauntlet will disrupt the market of HEMA gloves, as it shows people that high impact protection and natural freedom of movement *can* go hand in hand. As a result of this, a whole set of different techniques can be used during HEMA battles, that are impossible or dangerous with other gloves.



The ProGauntlet is therefore not only a product that is technically superior to its competitors: it creates a whole new meaning for the users. Such a combination of radical innovations in both technology and meaning are described as "technology epiphanies" [21].

RADICAL INNOVATION = CHANGE OF FRAME

Unlike incremental innovations, which are "improvements within a given frame of solutions", radical innovations are "a change of frame" [21]. In the HEMA context, the ProGauntlet has arguably changed the frame of the product and the performance in the sport.

The meaningful change for HEMA practitioners that it enables also justifies the much higher price of the ProGauntlet in comparison to its direct competitors.

RADICAL INNOVATION ≠ RADICAL INNOVATION

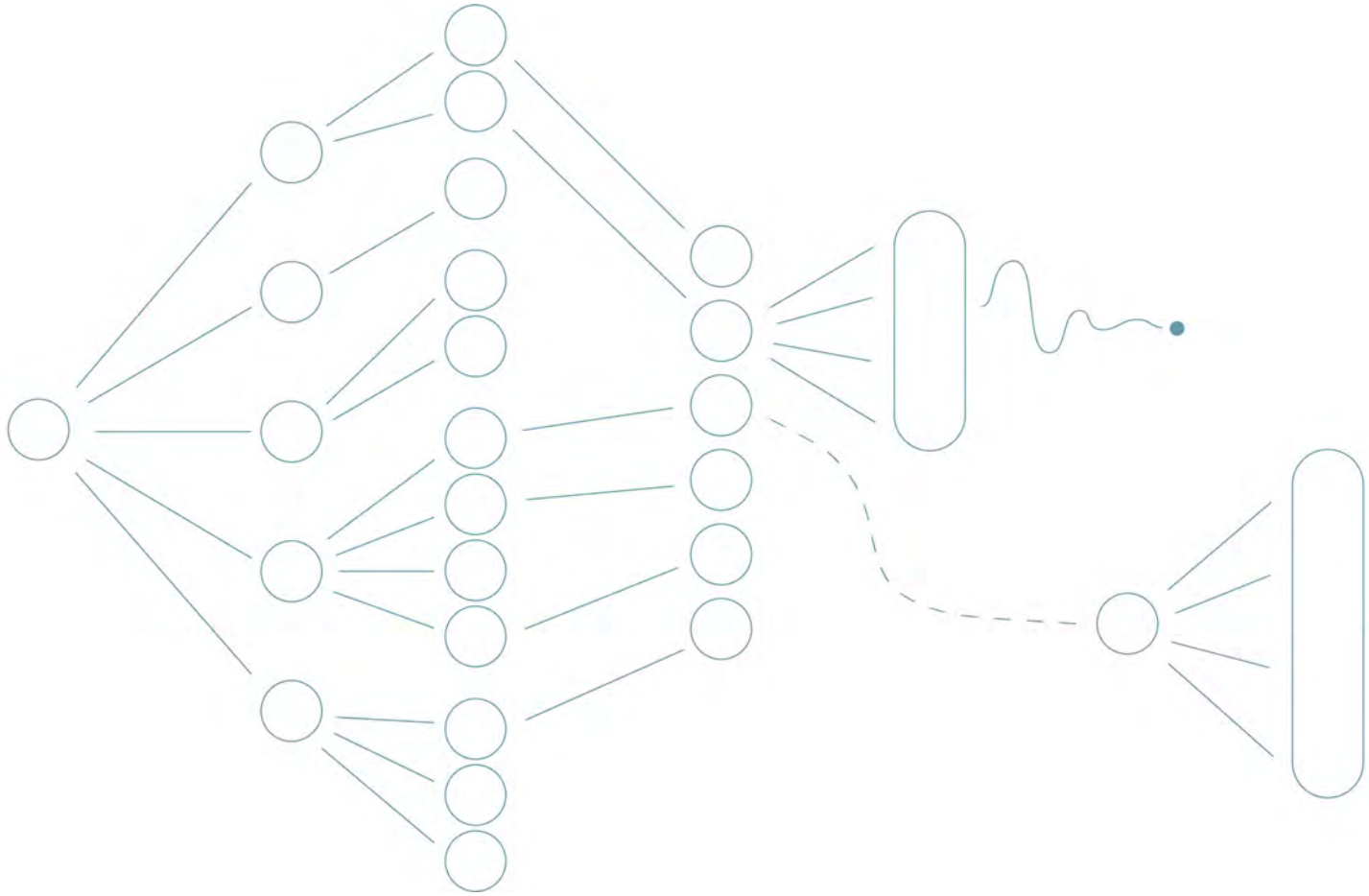
Sadly, being considered a radical innovation or a technology epiphany in the scope of HEMA gloves this doesn't automatically translate to being a radical innovation in the scope of hand protection in general. The glove doesn't necessarily create the same change in meaning in a different context. Successful radical innovations are rare occurrences [21], so succeeding in the HEMA market is already a great achievement for the ProGauntlet.

The research has shown that many of the design elements of the ProGauntlet have no real purpose, meaning or added benefit in the other scenarios. In other words, the qualities of the ProGauntlet don't match those use cases. The ProGauntlet is undoubtedly an impressive product, but if its features don't match with the context of use, then it has little added value in that context.

It could even be argued that since the ProGauntlet is so different from any other (known) impact glove in a technical sense, it is pointless to enter other markets if it is unlikely to create an innovation in meaning in these markets. If the design doesn't make any sense in the given context, consumers are unlikely to accept it.

Therefore, the next market must truly benefit from the type of protection that the ProGauntlet or a redesigned glove can offer. Besides improving safety, it must enable a positive change in behavior in the given market. Enabling such a meaningful change will make it much more valuable and relevant, which in turn are underlying factors of success.

6. The next market for a redesigned glove



Field Hockey

Earlier in this report, field hockey had been discarded as a non-viable market for the ProGauntlet, but that was with the requirement in mind of having minimal to zero design changes. With design changes, field hockey actually looks like a very promising market, as there is a lot of room for improvement and the complexity of the design would be relatively low.

Key points of this chapter

- Based on the research done during this project, field hockey appears to be the most interesting market for a redesigned protective glove. Partially due to this research, CrossGuard has started developing such a glove for field hockey.
- A field hockey glove will need to be extremely flexible, lightweight and breathable to have a chance at being accepted by the consumers. Offering better protection is also important, but the aforementioned qualities can be dealbreakers for many field hockey players.

Why Field hockey?

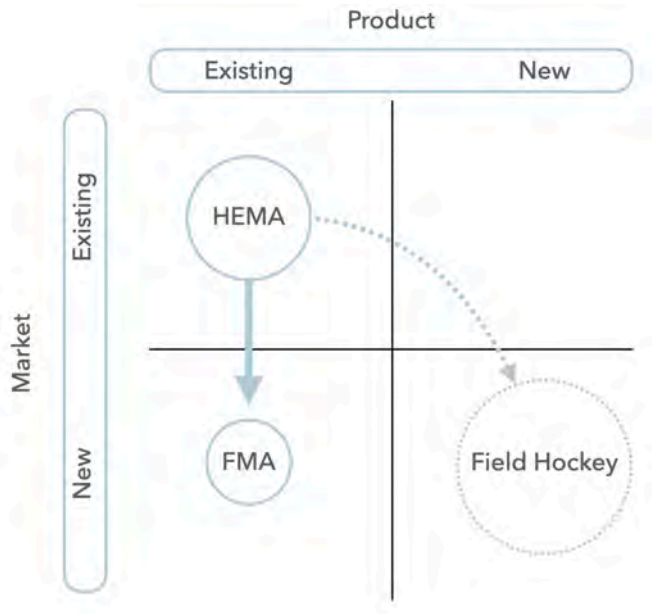
The ProGauntlet in its current form might not be useful for field hockey, but the *type* of protection may be very valuable for hockey players. There appears to be a dissatisfaction with the current design and quality of field hockey gloves. Hockey players need a stronger, more flexible, lightweight impact glove. This sounds like something that CrossGuard can make.

At the start of this research CrossGuard clearly stated that they did not want to make any (major) design changes, but this attitude has changed. Now a redesign is an option, and a redesigned hockey glove could be a logical next step for CrossGuard. When taking the principle of preventing injuries, the field hockey market poses the greatest opportunity for CrossGuard, of all the researched markets.

Current problems in field hockey

Many hand injuries

The prevalence of (serious) hand injuries appears to be very high in field hockey. This is found in the literature, and it is also confirmed by the players that were interviewed. All players that were interviewed in this study, as well as the players that were interviewed in an informal



manner, all of them had either experienced hand injuries themselves or had knowledge about serious cases in their direct environment.

Compared to similar sports, it appears that there is a negative correlation between the level of protection and the number of hand injuries in ice hockey, lacrosse and field hockey. The amount of metacarpal, finger and thumb injuries appears to be significantly higher among ungloved field hockey players, compared to gloved athletes in ice hockey and lacrosse [11, 19].

In field hockey, hand injuries seem to be a widely experienced problem, but the acceptance of these injuries is very high. This injury acceptance might have to do with a lack of good hand protection, as people choose not to wear protection for various reasons.

Scraping the knuckles appears to happen to everyone, every match, and bruised fingers, thumbs and knuckles also seem to be quite common. Serious injuries include fractured fingers and even (almost) amputated fingers.

"When defending, your left knuckles are usually facing outwards, so that's where you get hit most often."

"If you put your hand on the ground, the skin on your knuckles will rip open with even the slightest movement."

Traumatic hand injuries

Luckily, most injuries appear to be limited to bruises, which usually don't have a lasting effect.

Traumatic injuries, on the other hand, do also happen relatively often unfortunately. Multiple instances of broken fingers were mentioned, and two of the participants knew at least one (different) person who had almost lost part of a finger due to an impact from another stick.

"Last year, there was a girl on my team who almost lost half of her finger. I don't know how it happened exactly, but I think her finger got crushed between two sticks. She's missing a part of her fingertip now"

"I've never broken anything myself, but I do know people who have had broken fingers. One guy even almost lost his finger. An opponent was aiming for the ball, but missed, so his finger got slammed between two sticks. Then his index finger was only hanging on his tendon from the middle phalanx."

Blunt impact

- Contact with an object (mostly the ball or a stick) accounts for 35% of all serious injuries during field hockey [22].
- This aligns well with the protective qualities of the ProGauntlet.

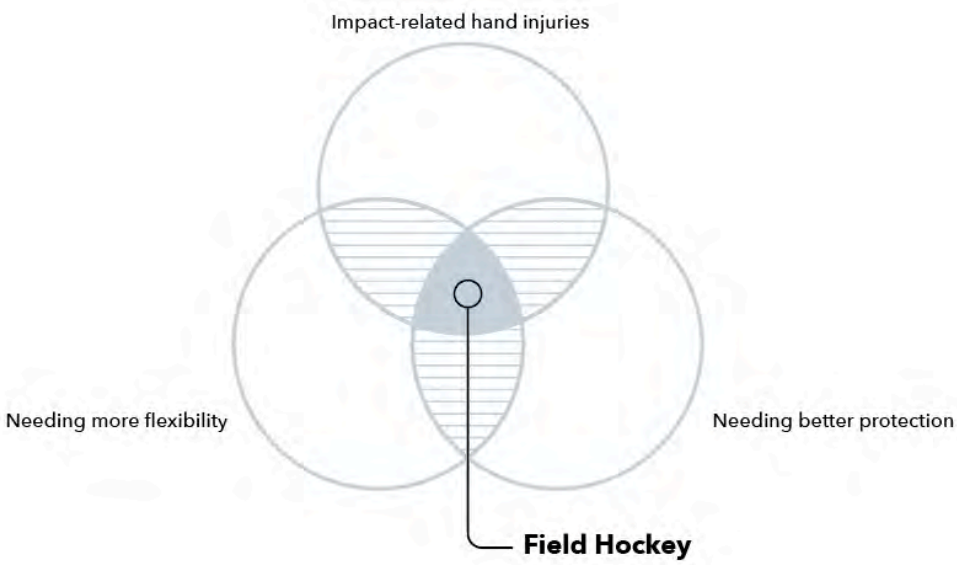
"Most of my hand injuries were caused by another stick. Or a ball. I don't know. Actually both happen quite often."

Validation of the need for a better field hockey glove

The issues around current field hockey gloves and possible improvements were discussed with a number of players and other relevant people:

- Two coaches of two different national field hockey teams
- Several players of a national field hockey team
- A former (retired) goalkeeper of a national field hockey team
- Three semi-structured open-ended interviews with amateur hockey players of various levels
- Around 10 players of various levels in the Netherlands, both for field hockey and indoor hockey. These players are in the age range of 20-30 years old, both men and women.
- Other insiders in the hockey market

Many valuable insights about the context of field hockey were obtained through these discussions.



Needing better protection

One of the most obvious problems with the current (short-fingered) hockey gloves is that they don't fulfill their basic function: preventing hand injuries. Players mentioned that they had experience with or knew about injuries that happened even while wearing a glove.

Even while wearing a glove, people still sustain hand injuries during field hockey. Besides the physical toll that this takes, this also leads to a change in behavior among many players.

"Sometimes you pull your stick up and let a ball through, because you know that your gloves aren't strong enough."

Glove wearing

- The amount of players that wear gloves varies per team. One coach of a national field hockey team said that **around 40% of his team wears a glove**.
  - They only wear a glove on their left hand. The amount of people wearing a glove around their right hand is negligible. Hand dominance usually does not play a role.

Why many players don't wear gloves

Despite the relatively high prevalence of hand injuries in field hockey, people often don't wear protection because it's uncomfortable, bulky, smelly and just because they don't really see the necessity of it.

SWEATY

"I don't wear gloves during hockey. It's sweaty."

TOO BULKY

Bulky gloves affect the performance negatively. Many players are therefore willing to take the risk of wearing less protection or even no protection at all, in order to perform better

"In terms of hand injuries, I've broken a thumb once, while defending, […] but I still choose not to wear a glove. It makes my hand too thick, it sticks out too much."

UNCOMFORTABLE

"I had a glove once that had a Velcro strap. That constantly scraped against my other hand and even made wounds."

Open to improvements

"Maneuverability is actually the most important factor for a glove. After that comes grip, then weight and size. If it also protects well, then that's nice. If a glove has all those features, then it's really just stupid not to wear one."

Factors influencing glove use

Level of play

The choice on whether or not to wear a glove can be influenced by many different factors, but one factor appears to be consistent: the level of the players. It seems that more advanced players, who play at a higher level, wear a glove more often than those competing on a lower level.

- The amount of serious hand injuries such as fractures is low in the national teams. This aligns with some of the findings from earlier interviews. In those interviews, multiple participants said that they were more afraid of getting injured when playing less experienced teams.

The research indicates that the risks of hand injuries differ between elite and amateur players, as does the choice for wearing a glove. At higher levels of play, the intensity is higher, but the precision of every action on the field is also greater. High level players play harder, but they know what they're doing, whereas novice players are less adept in predicting situations and acting accordingly. This can lead to mistakes and possibly injuries.

- Elite players: harder contact, more intense playing, but with more precision. Able to anticipate the ball trajectory and the actions of other players much better. This might allow them to prevent some injuries.

- Novice players: unpredictable, prone to making mistakes, but usually a lower playing intensity

"If you look at those pros, they all wear gloves, or most of them anyway."

"There are 16 girls on my team. I think ten of them wear a glove."

(high-level midfielder)

"I don't wear a glove myself, and there aren't a lot of people on my team who do. About 2 out of 11 wear a glove on my team."

(midfielder, playing in a recreational team with his friends)

Influence of others

One other player, an attacker, said that he did wear a very slim glove on his left hand. He started wearing this after his former coach made it mandatory for the entire team to wear gloves. After switching teams, he continued wearing the same protection, since he was afraid of hurting his hand if he would take it off. He described this as a feeling of "bad karma". He did point out that the glove affected his performance slightly and that he would like to be able to play without protection. He would not consider wearing bulkier protection, even if it protects better.

"Some guys have been wearing a glove since their childhood. Their parents said that they should wear one, and then they continued wearing it."

"I started wearing a glove for my own safety and because my coach advised it"

Conclusion

The ProGauntlet in its current form is not useful for field hockey, for various reasons. The *type* of protection however, may be very valuable for hockey players. This, in combination with the high number of hand injuries and the amount of room for improvement there is, makes it interesting to explore the opportunities in this field.

According to the original project brief, the answer for field hockey would be a loud and clear "no", when it comes to introducing the ProGauntlet in this market. When thinking about the product in a broader sense however, field hockey does seem to align with the qualities that CrossGuard can provide in a glove.

There appears to be plenty of interest in a field hockey glove that effectively solves the current problems. CrossGuard could use this as an opportunity to develop a glove that offers better protection than the competition, while being much more flexible at the same time, among some other qualities.

High-tech product in a low-tech market

In a way, the current situation in the field hockey market is somewhat similar to the situation in the HEMA market. With the ProGauntlet, CrossGuard has entered a low-tech market with a high-tech product. The overall level of innovation and R&D in the HEMA market was very low until the introduction of the ProGauntlet. This glove has shown that HEMA gloves are a serious product. For field hockey, CrossGuard might be able to achieve a similar effect. There is a lot of room for improvement in the field of hand safety during field hockey.

Solving the problems with the current gloves seems to be something that is within the reach of CrossGuard's capabilities.

Accessible market

An additional benefit is that hockey is a very accessible market in the Netherlands, which can make it easier for CrossGuard to design, test and iterate the design. This is why it would be wise to focus on the field hockey market for the first redesign of the ProGauntlet.

Redesign suggestions for a field hockey glove

At the time of writing, CrossGuard is already designing a field hockey glove. As it is still in an early stage of development and because CrossGuard would like to keep their design confidential for now, the design of the glove is not included in this report.

The actual design of the glove also isn't really that important for this report. The qualities of the glove are far more relevant. Based on the research, there are a number of qualities that the glove should possess, in order to effectively differentiate itself from the other gloves and to add a significant value for hockey players.

Protection vs. freedom

In contrast to HEMA gloves, where extreme protection is more important than the freedom of movement, field hockey players often choose not to wear a glove at all if they feel that it restricts their movement. The glove that CrossGuard will produce therefore should not (and at the time of writing *does* not) not impede the hand's functioning in any way. The users should be able to move their hands as if they're not wearing a glove at all.

Functionality

- The glove must solve the most important problems effectively
  - Must not limit hand movement in any way. Movement is probably more important than protection. If people want maximum protection, they are likely to give up movement, but not the other way around.
  - Not sweaty, or easily washable
  - Abrasion resistance

Safety

- Official hockey rules: "Players must not wear anything which is dangerous to other players" [23]. It is important to take into account that if the hockey glove will have a hard outer shell, then it cannot pose a risk to other players in any way.

Esthetics

- Use the shell structure as a feature: make very clear that this glove is different from the other gloves.

Breathability

Having an open structure on the back of the hand would make it much less sweaty. Perhaps a perforated back, or just as an open frame.

Other situations

Indoor vs. outdoor hockey

Field hockey is most often played outside, on a surface of artificial grass, but (mainly during the off-season) it can also be played on an indoor pitch. An indoor hockey pitch is much smaller than an outdoor field, and is usually the same size as a basketball pitch. Because of the smaller playing field, players stand much closer to

each other, and therefore it is generally more likely to get hit by a ball or another stick.

The basic rules of indoor hockey are mostly similar to field hockey, but there are a couple of important differences. Most importantly, the ball may not leave the ground unless it is shot directly at the goal. Because of this, the hands and the stick are held much closer to the ground by players.

The combination of a smaller field and being closer to the ground makes the risk of hand injuries during indoor hockey much greater than during outdoor hockey.

Despite this, field hockey is a much bigger market than indoor hockey, and good field gloves could (perhaps) also be used indoors. Therefore it is likely more interesting to focus on an outdoor glove first. Good outdoor gloves don't seem to exist yet, and indoors people are more willing to trade freedom of movement for protection.

"During indoor hockey, I'm willing to trade some of the freedom of movement for better protection, because I know how important. good hand protection can be."

(high-level midfielder)

Penalty corners

According to the coach of a national hockey team, every team has four pairs of gloves for the corner defense. Nowadays, especially due to COVID-19, teams even have eight pairs of corner defense gloves. These are often ice hockey or cricket gloves. The sizes of these gloves is named as a benefit, since the surface area helps with defending the goal. The permitted dimensions of the gloves are therefore limited [23].

Although the big gloves that are used during penalty corners protect well and their size can make it easier to block shots, these gloves make it difficult for the players to make follow-up actions. They need to take them off and throw them away, outside of the playing field, losing valuable time. Increased flexibility and better stick handling of penalty corner gloves would be welcome improvements, but the hand protection is already adequate according to the players and coaches.

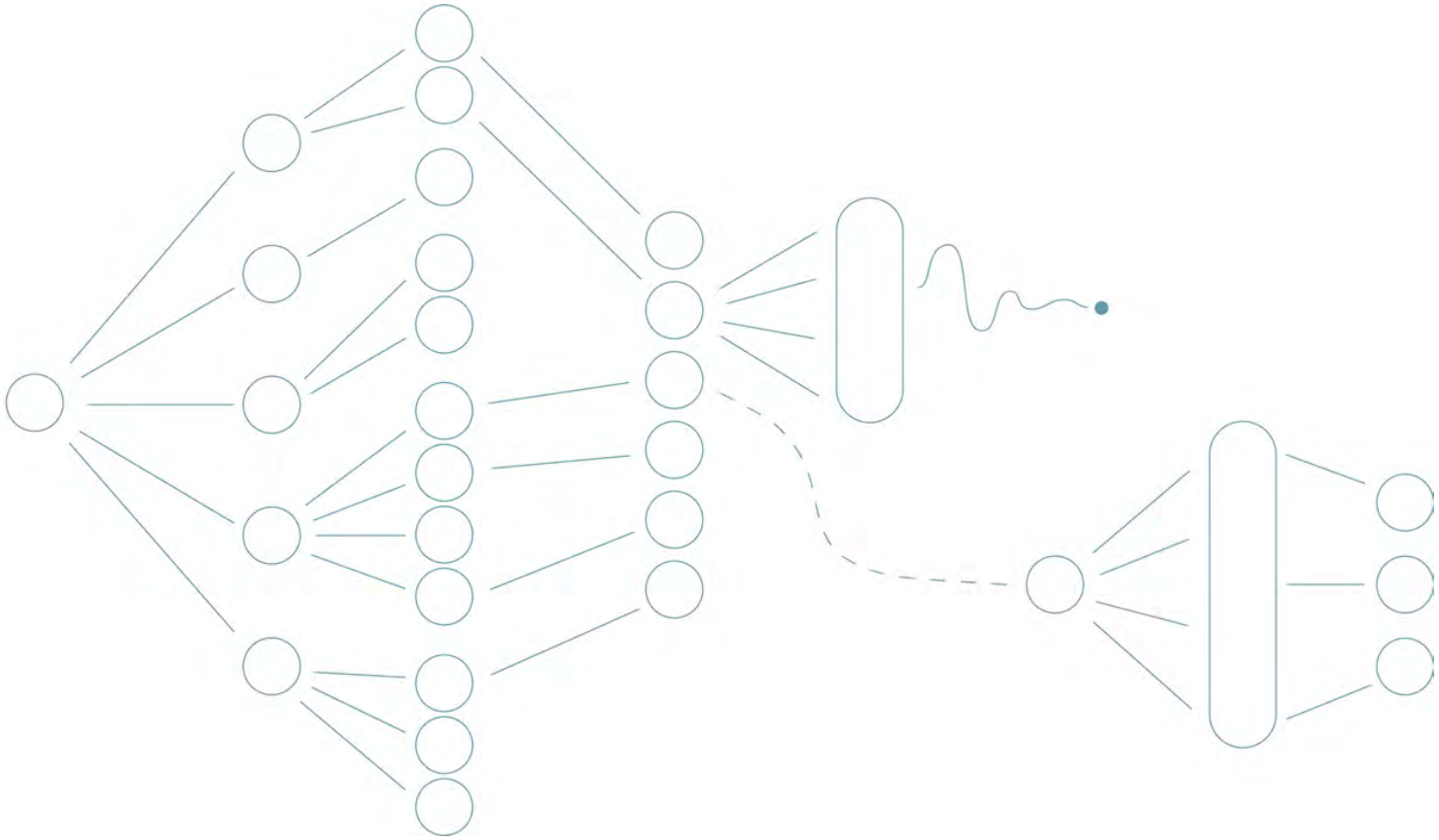
If each team really has 4 to 8 pairs of gloves for penalty corners, then this would be a highly interesting direction for further research. An investigation among "average" hockey players revealed that only the elite teams actually have (and use) this many gloves. During amateur games, many people don't wear gloves at all during penalty corners and if they do, they share a couple of pairs between multiple teams within a club.

During penalty corners foot and ankle injuries are currently a bigger problem., but those will require a completely different product. Perhaps CrossGuard can design this in the future, but at this moment it does not seem to be a logical step to take.

Goalkeepers

Goalkeepers are an unlikely target group for CrossGuard. The priorities of goal keepers are different from other players: aside from good protection, they also need to create the largest surface area possible. Therefore they wear big, thick foam padding that sticks out on all sides of their body, to block more shots. Besides a large surface area, they also need maximum rebound of the material, to kick or punch the ball as far away as possible. There are some areas of their protection that could potentially be improved, like the thumb protection and the elbow pads, but these are completely different products from the ProGauntlet.

7. Branding strategy



4C analysis

Competition

Competing brands

There are a lot of competing brands in the field hockey market. The competitors include: Adidas, Grays, Osaka, Dita, Brabo, TK, Gryphon, The Indian Maharadja, Reece Australia, Naked, Malik and Princess.

With so many competitors, it is difficult to estimate a potential market share for CrossGuard.

FOCUSED VS. DIFFUSED

Most competitors focus on the entire hockey market, offering a whole range of different products for different types of players. Some companies focus more on stick technology, while others have more of a one-stop shop approach where they offer every single piece of hockey equipment: sticks, shoes, clothes, etcetera. Not a single competitor has gloves as their main focus. This is a point where CrossGuard can differentiate itself from the competition. By only making hockey gloves, they can position themselves as 100% focused on making the ultimate glove, as opposed to the other companies, which are all diffused, scattered about many different products.

The only other "focused" brand is OBO, which sells equipment specifically for goalkeepers. This makes their products much more specific and lets them use highly targeted communication. Besides OBO, there isn't a single brand in the hockey market that is completely focused on one product.

What do the competing brands want?

- Difficult to judge, but as the the hockey market isn't growing very rapidly, it is likely that most competitors want to hold on to their market share.
- There are a couple of relative newcomers on the market that do have a different strategy form the older brands. One example is Osaka, which positions itself as a combination between a hockey brand and a Japanese-inspired lifestyle brand.

Competing hockey gloves

All of the competing companies also sell gloves, and they are all highly similar to one another. There are a couple of general types of hockey gloves:

- Short-fingered hardshell gloves with an open palm. The designs of these gloves are all very similar, with none of the brands strongly differentiating itself through their gloves.

- Full finger, thick padded gloves for maximum protection and/or indoor hockey. Usually with a grippy palm.

- Full finger gloves with light padding. Basic protection, mostly for indoors.

- Short-fingered foam gloves. Covered palm and often without thumb protection.

The most direct competition for CrossGuard are the first one on the list: the short-fingered hardshell gloves with an open palm. These are mainly used outdoors and aim to offer protection against scraping of the knuckles and decent protection against the occasional unlucky shot or stick on the hand, while keeping the stick feel as natural as possible.

The user research has shown that there are various problems with these gloves:

1. They lack flexibility. To illustrate this: during a user test it became clear that moving the hand and fingers while wearing the ProGauntlet is actually easier than in one of these "slim" hockey gloves. Therefore it can be assumed that CrossGuard can design a much more flexible hockey glove.

2. They don't protect well enough. Users reported that these gloves might prevent some injuries, but that it's still possible to break your hand or fingers if you get hit by a ball or a stick at full speed. Here too, it can be assumed that CrossGuard can do better than the current gloves. The ProGauntlet proves this.

3. They're sweaty. The material on the back of the hand doesn't breathe well, which makes it sweaty, smelly, itchy and dirty after a while (this was confirmed in the user research, which involved smelling a used glove). Since CrossGuard will likely have a different type of shell protection, they can most likely make the back of the hand ventilate better, for example by removing unnecessary parts of the shell.

- Bottom line: CrossGuard can do better than the current field hockey gloves.

If CrossGuard can offer a superior alternative that is radically different, they might be able to get a substantial market share.

Levels of competition

PRODUCT FORM

- Flexible, short-fingered hardshell hockey gloves

PRODUCT CATEGORY

- Short-fingered hardshell hockey gloves

GENERIC

- Hockey gloves

BUDGET

- Hockey equipment, other protection

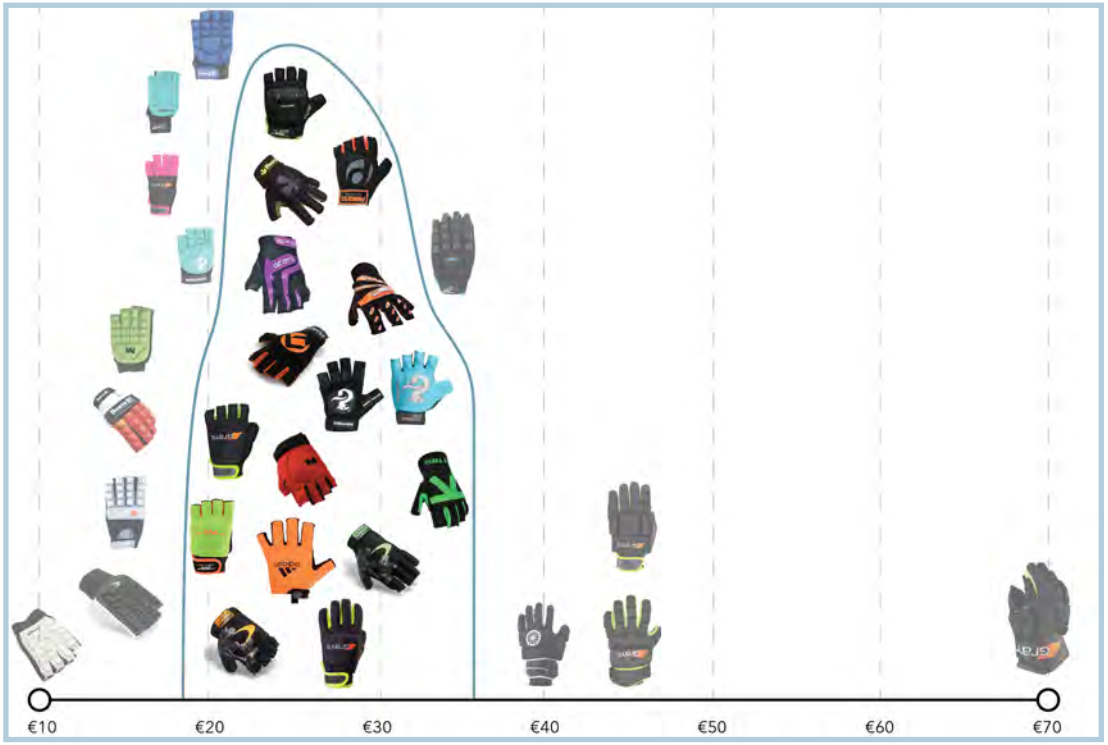
Price range of competing hockey gloves

Every single hockey brand has a similar type of short-fingered hardshell glove. The most direct competitors are outlined in the graph. These gloves are all in the price range of €20-€35. Most of them cost €25. Other types of hockey gloves are also shown, as a reference.

Price of CrossGuard's hockey glove

With its hockey glove, CrossGuard offers substantially better performance than any of the competing gloves. Therefore it would be logical to place the product at the higher end of the scale. The most expensive competing hardshell glove costs €35. The exact price of CrossGuard's glove will need to be determined through a more thorough financial analysis, but a price of around €50 per glove would be considered reasonable, looking at the competition's offerings. During the user interviews, participants also named such prices as reasonable. In some cases they were even willing to pay more. The quote below illustrates the thought process of one (potential) user:

"If it really works extremely well, then 60 euros would come to mind as the absolute maximum in terms of price. A hockey stick is about 100 euros, shoes are about 100 euros, and those are the most important investments that you have to make. People often are like: a new stick one year, a new pair of shoes the next year."



Context

Market size

There are about 2.4 million field hockey players worldwide, of which almost 1.5 million players are located in the USA. With around 255,000 players, the Netherlands are the second largest field hockey nation in the world in terms of absolute numbers. When it comes to the relative popularity of the sport per capita, the Netherlands are easily the number one field hockey nation of the world.

The way in which the sport is practiced differs greatly between these two countries.

Hockey in the USA

HIGH SCHOOL & COLLEGE HOCKEY

In the USA, field hockey is largely practiced in high schools and colleges. Almost 64,000 US teens compete in high school field hockey [24].

As for college field hockey, over 300 US universities have field hockey teams. Those are all women's teams, college field hockey is not offered for men in the USA. College field hockey is most popular in the northwestern states of the USA, but its popularity is spreading through the rest of the country as well [24].

COMPETITION WITHIN TEAMS

- Most college field hockey teams have **20 to 25 players on the team, even though only 11 players are on the field during a match.**
- This creates a **very competitive atmosphere within the team**, to secure a spot on the field. This creates an incentive for the players to go all-out, not only to win the match, but also to belong to the top players of the team [24].
- This pressure can lead to players taking more risks, which may result in injuries.

NO TIME FOR INJURIES

Besides having to perform well on the field, there is also a substantial amount of pressure to perform well in class. They need to pass courses in order to continue their degree, (possibly) keep their scholarship and to avoid paying for an extra year of tuition.

In this pressured lifestyle, there is no time for broken hands. They need to be able to perform at their best, both on and off the field, always. The same applies for people who have gig jobs, not wanting to risk losing (temporary) functionality in their hands.

Hockey in the Netherlands

In the Netherlands, field hockey is not bound to educational institutions, but through separate clubs instead. Many of these clubs have a vibrant social culture, which makes field hockey a social activity as much as it is a sport in the Netherlands.

DEMOGRAPHICS

The hockey population in the Netherlands is arguably more diverse than in the USA. Women represent 62% of the field hockey population in the Netherlands [25]. The user research suggests that gloves are more popular among women than among men.

INCOME

Even though hockey is a highly accessible sport in the Netherlands (anyone can join a hockey club, instead of being regulated by schools), it attracts a relatively wealthy and highly educated segment of the population [26].

Hand injuries

- The direct medical cost of a hand or finger fracture is around 1000 euros on average in the Netherlands. Hand and finger fractures are the most expensive injuries in the context of hockey, both in direct costs per injury, as well as the combined costs for the entire hockey industry [22].
- In total, **85% of all hand injuries in field hockey in the Netherlands happen to players up to 24 years old** [22].
- The younger population has more injuries in total, but in relation to the number of hours played, men between 35 and 54 years old are more prone to serious injuries. The question is however, if these players are likely to change their behavior [22].

Wearing gloves

The exact proportion of players that wears a glove is unknown. Prior estimations are very rough and vary between sources. Most of them are "guesstimations" (somewhere between a guess and an estimation). Rough estimations based on user research and data from Crossguard suggest that over half of female players wear a glove, and around 40% of male players. In total, this would amount to almost 50% glove use among all players. These numbers are far from a certain though, so they should be interpreted with caution. The results of the user research varied greatly between different respondents.

LARGE VARIATION

If anything, the user research has shown that the proportion of glove users varies greatly between different teams. This might be influenced by many different factors, such as level, teammates, age, etcetera. It is unclear how each of these factors influence one's choice to wear gloves, but it appears that the direct (social) environment plays a large role. Parents, coaches and teammates can potentially convince players to wear a glove. This has been confirmed by multiple interviewees who wear a glove due to this reason.

SPILLOVER EFFECT OF GLOVES

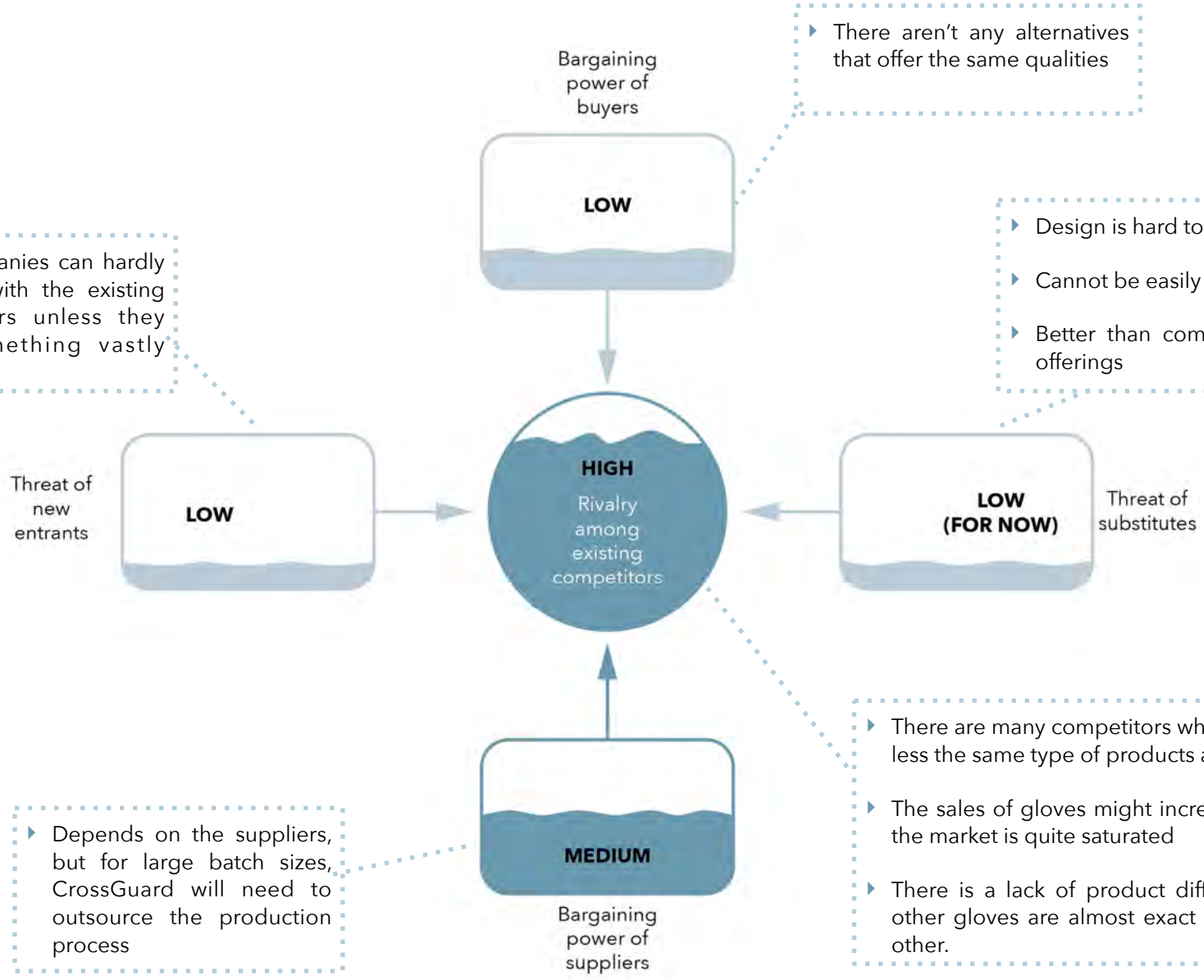
Interestingly, in teams where people wear gloves, it seems to be more likely that a large portion of the team starts wearing a glove. In teams where few or none of the players wear a glove, there is also less awareness about glove wearing.

LEVEL OF PLAY

On higher levels of play, the ball can reach speeds of more than 100 km/h. An impact from such a shot can cause serious injuries. For this reason, glove use is generally more common among high-level players [27]. Even while wearing a (current) glove, a full-on impact at such a high speed can cause hand fractures, according to some of the interviewed players.

Industry analysis

PORTER'S FIVE FORCES [28]



Consumer

Ambitious field hockey players

Ambition isn't tied to a certain level: it's a mindset. For the ones who dare to work hard, for a better world, for a better self. Ambition doesn't stop when you achieve your goals: it only strengthens it. Ambition is a perpetual state of improvement.

HAVING OTHER RESPONSIBILITIES

Unlike elite football players, most hockey players don't earn their living by playing hockey. Aside from the very best players who compete at the highest level and/or in a national team, almost all field hockey players have another job, go to school or study. Therefore it's important that players can perform at their best not only on the field, but also off of it. Getting injured doesn't only mean missing a couple of matches, getting injured limits your ability to live your life.

This is especially true for younger players: teenagers and young adults who have busy lives, combining hockey, a vibrant social life and school and/or work.

Wearing gloves

The field hockey market is divided between people who wear a glove and those who don't. The players who don't wear a glove often have personal reasons for this, often related to comfort and stick handling.

The players who have made concessions in both performance and protection will benefit most from this glove. These are the players that wear the current slim hardshell gloves, which don't protect well enough and also limit the movement of the hands.

Players that really want the ultimate protection are likely to be willing to trade freedom of movement and other qualities in order to get that protection. For those, the difference would be that the protection is less of a burden, but it probably won't change their mindset as much.

Segments

Although selling as many gloves as possible in the entire market is the main goal for CrossGuard, there are a couple of interesting segments for this product within the field hockey market.

AGE GROUPS

In general, the proportion of glove-wearing players appears to be higher among young hockey players, since parents and coaches have a direct influence on the choice to wear gloves. Many of the players that have started wearing a glove at a younger age, as instructed by their coach or parents, continue to wear a glove when they're older.

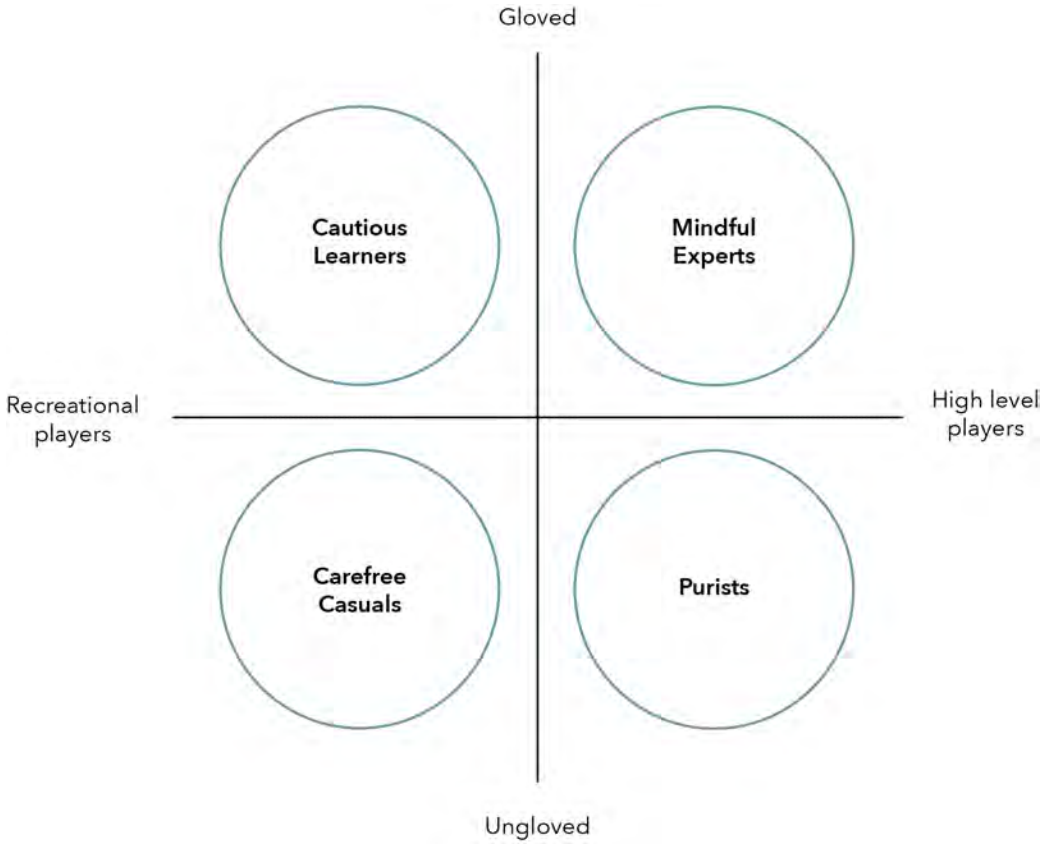
"More and more gloves are being sold. I think this is because parents want their children to be protected better, as the speed of the game is increasing."

Many of the adults that play hockey can, at best, be converted to wear gloves, but it may be difficult to make them change their habits

CORPORATE HOCKEY TEAMS

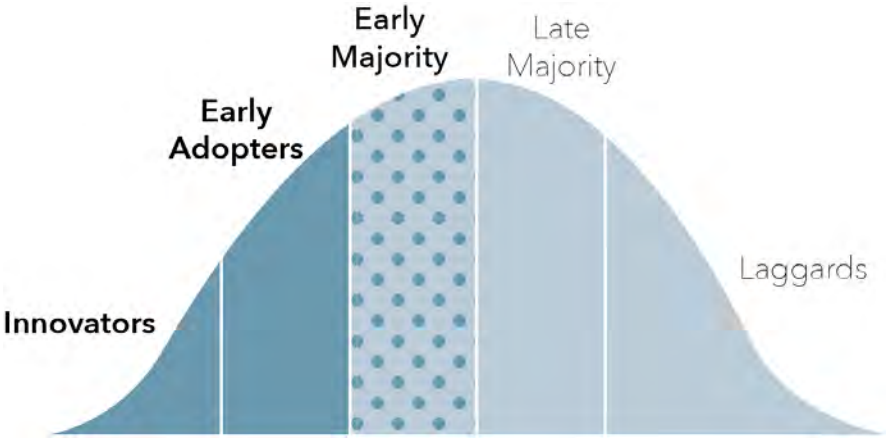
Field hockey is one of the largest sports in the Netherlands, and this is reflected by the existence of a segment of hockey players that isn't

seen in other countries: corporate hockey. Teams of different companies compete with one another. Naturally, these people all have a (serious) job and therefore they themselves and the company want to avoid getting injured during a hockey match. This segment has a clear incentive to improve their safety in any way possible, and therefore would be a likely segment to sell the glove.



Different player types and readiness to adopt the new hockey glove

Based on the model for diffusion of innovations by Rogers [29], combined with the research insights, a general prediction of field hockey players' attitude towards the new type of hockey glove is made:



- **Innovators:** Players who already wear a glove and want to have the best equipment, to perform the best. These people just need to have the newest and best stuff.
- **Early adopters:** Players who already wear a glove, and are frustrated with the problems of their gloves. Likely also includes people who have experienced hand injuries before.
- **Early majority:** First-time glove users that have been contemplating to wear a glove, but weren't convinced by the other designs. Also glove-wearing players who need to replace their glove.
- **Late majority:** Players who currently don't wear a glove, but might be motivated to wear one when they see everyone around them wearing a glove.
- **Laggards:** Players who only wear hand protection if it is absolutely mandatory. If everybody around them wears a CrossGuard hockey glove, then they have a clear disadvantage. This could make them switch, but the motivation will be extrinsic rather than intrinsic.

The hockey glove by CrossGuard will definitely be interesting for the innovators, as they are always after the newest equipment. If the glove can really perform as well as expected, then the early adopters will likely also be drawn to it. These are likely the people who are frustrated about their current glove, but have worn it nevertheless as they are aware of the risks.

If CrossGuard effectively collaborates with high-level players of national teams, like they are doing now, then this would add a lot of extra credibility to the glove for the innovators and early adopters to buy it.

Targeting the late majority and the laggards in this stage is pointless, since the product still needs to be launched and then needs to prove itself. These two groups aren't naturally drawn to new innovations, so these should only be targeted if CrossGuard has gained a solid foothold in the hockey market.

Company

CrossGuard currently has no experience or reputation in the field hockey market. The design is radically different from anything else on the market, so it is important to introduce it in a way that resonates with the consumers, who are used to the existing brands.

BRAND AUTHENTICITY

The Netherlands are home to many of the most popular field hockey brands, such as Grays, Dita and Osaka. CrossGuard has the advantage of being a Dutch company. The hockey heritage of the Netherlands adds to the brand authenticity on a national and international level.

EXPERTISE/RESOURCES

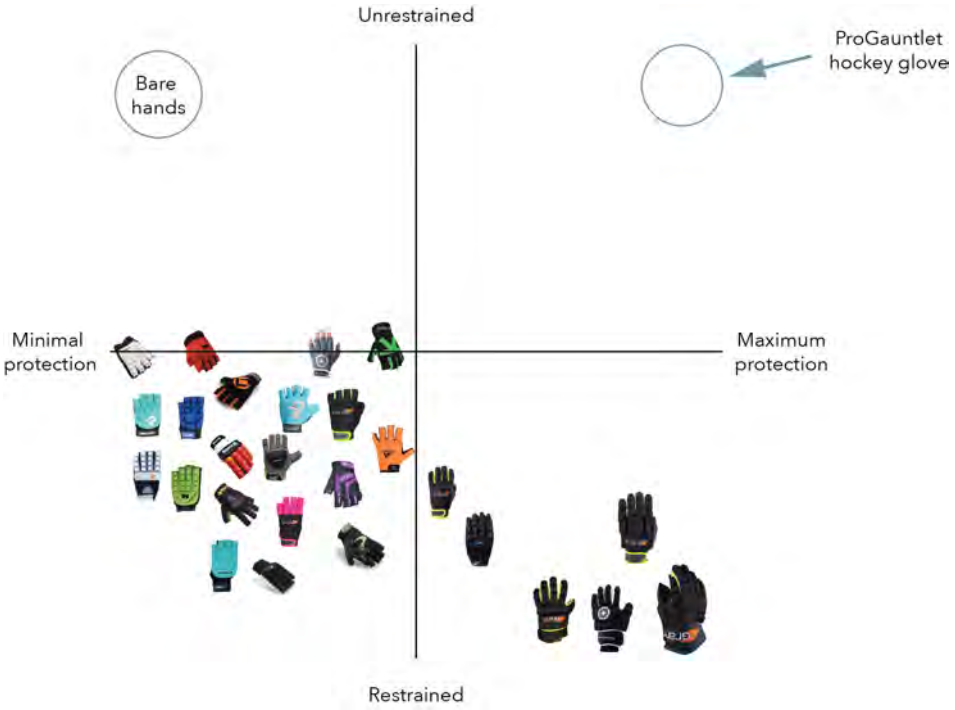
The company is completely focused on gloves, whereas gloves are seen as an accessory by the existing hockey brands.

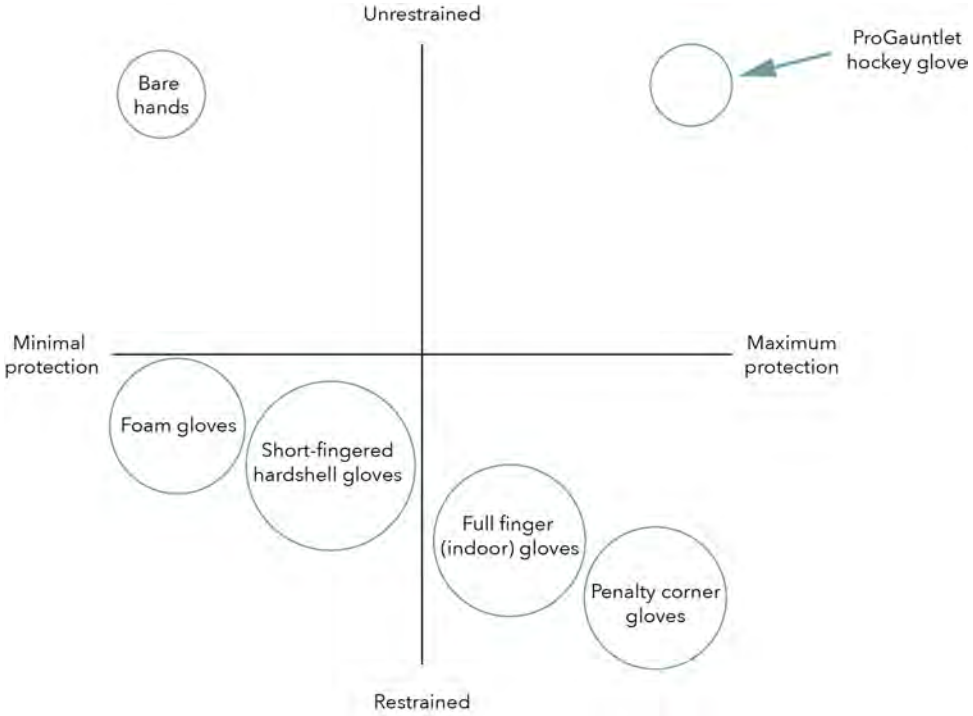
The company redefines the role of hockey gloves and brings gloves into the spotlights rather than in the background.

Competition axis

The recommended positioning of the brand is based on a bipolarity: ***unrestrained protection***. Instead of choosing for protection at the expense of performance, the hockey glove by CrossGuard offers both. With this positioning, a hockey glove becomes a performance aid instead of a limitation.

This positioning is the result of the 4C analysis, in combination with the qualities of the product and prior research. This positioning addresses the main concerns about the current hockey gloves and puts them into one clear bipolarity.





Unrestrained Protection

Unrestrained Protection

Live without restraints, through better protection

“Unrestrained protection” vs. “Protection without compromise”

Whereas “protection without compromise” sounds very similar to “Unrestrained protection”, the meaning is different in an important way.

Compromises are different in every context. Then the question is which compromises CG focuses on. The meaning of “unrestrained” is similar across all contexts, and therefore gives a much clearer image of what the company stands for.

“Unrestrained” refers to the action of the user: the user is not held back by the protection or limited in any way. It’s actually even stronger than that: the user can even perform their activity better *thanks to* the protection that they have. Swapping “without compromise” with “unrestrained” essentially changes the meaning of the product from “not limiting performance” to “enabling ultimate performance”.

In other words: “no compromises” more or less means “not worse” in this context, but doesn’t mean “better” either.

Unrestrained protection: HEMA vs. Hockey

HEMA

Ultimate protection with the freedom you need to make the most technical moves

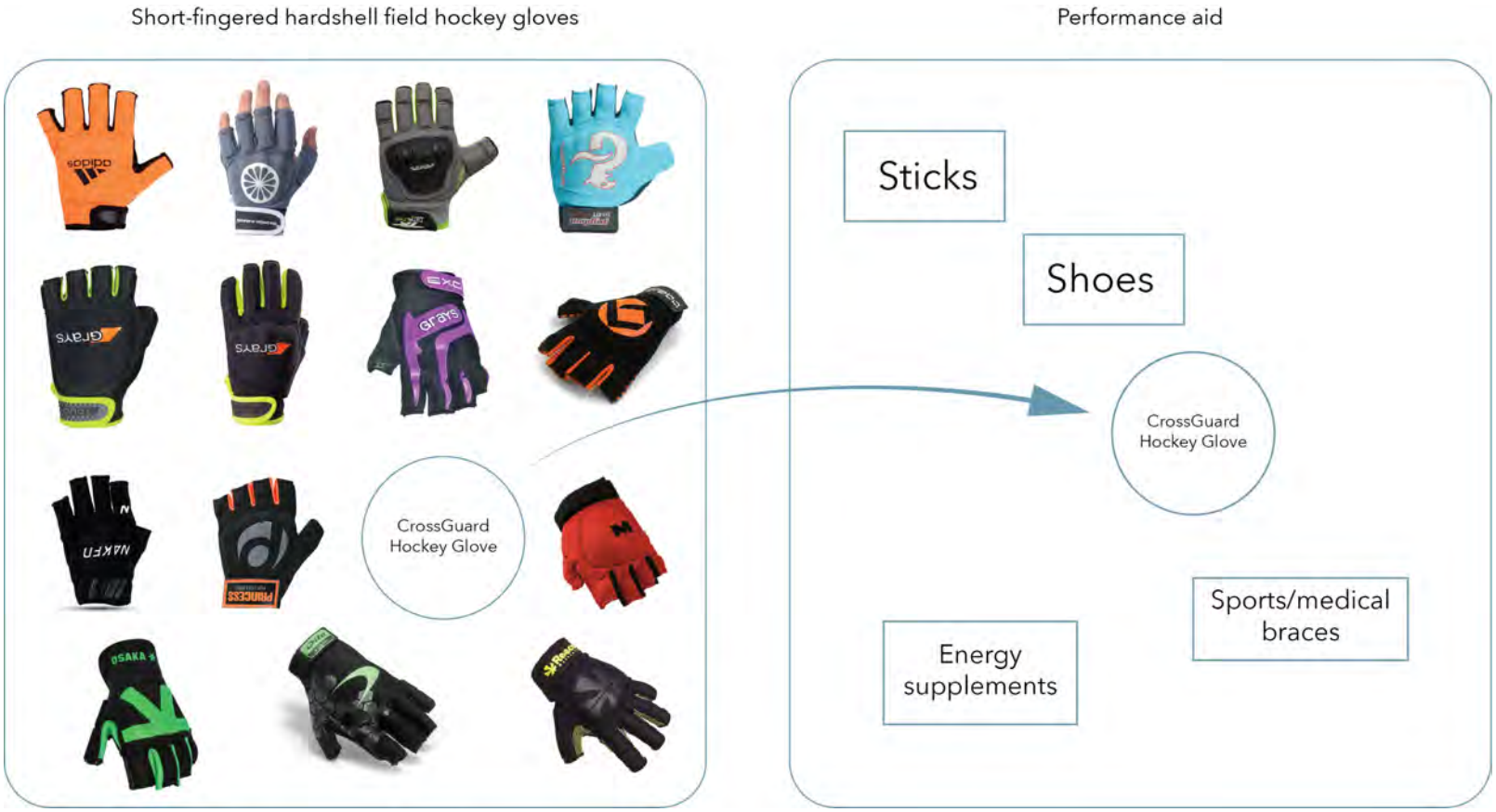
FIELD HOCKEY

High impact protection where you need it, with a bare-hand feel. Only noticeable in a good way.

From hand protection to a performance aid

By reframing CrossGuard's glove as a performance aid, it differentiates itself from the other short-fingered hardshell hockey gloves. By comparing it to a new category, it makes all the competing hockey gloves look even more similar to each other. Now, all of those are just more or less interchangeable with another: they are just average, performance-limiting hockey gloves.

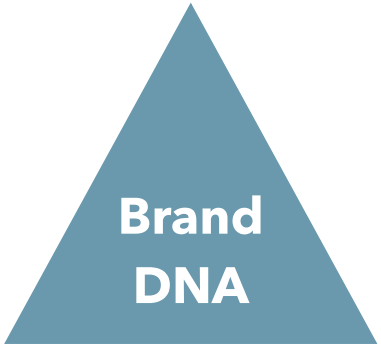
The hockey glove by CrossGuard is different. It becomes a tool that enables people to play better, more comparable to a like a high-end stick.



Brand DNA

Purpose

We believe that protection should expand one's possibilities, not restrain them.



Positioning

Ambitious field hockey players/ freedom/push their limits

Personality

Innovative, bold, no-nonsense, considered, hero archetype

Positioning statement

For **ambitious field hockey players**, **CrossGuard** offers **a hockey glove** that is **tough**, **virtually unnoticeable** and gives people the **freedom** to **expand their limits**.

The future: suggestions

“Unrestrained protection" across all products and brands

The beauty of the bipolarity of “unrestrained protection” is that it can be applied to the entire brand of CrossGuard and gives a clear direction for other products in the future as well.

“Unrestrained” refers to the action of the user: the user is not held back by the protection or limited in any way. It’s actually even stronger than that: the user can even perform their activity better *thanks to* the protection that they have. Swapping “without compromise” with “unrestrained” essentially changes the meaning of the product from “not limiting performance” to “enabling ultimate performance”.

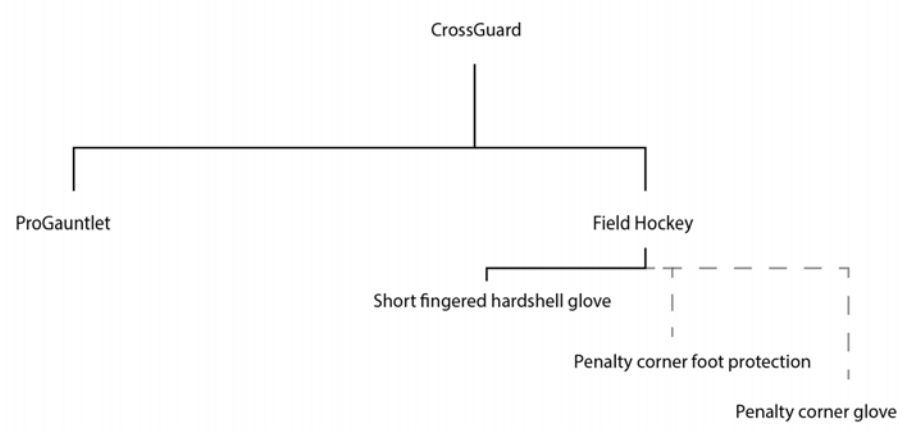
“Unrestrained protection” in different markets

“Unrestrained protection” can essentially apply to any type of protection for any activity, as long as it is something where the protection is holding back the users. During this project, the focus has been on gloves, since CrossGuard has a lot of expertise in this area. If they would want to produce other types of protection they aren’t restrained by their own philosophy.

CATEGORY EXTENSIONS IN THE FIELD HOCKEY MARKET

If the field hockey market can be entered successfully, then CrossGuard could expand its product portfolio further, in the form of category extensions in the hockey market. These could include foot protection and penalty corner gloves.

- Foot protection
- Penalty corner gloves

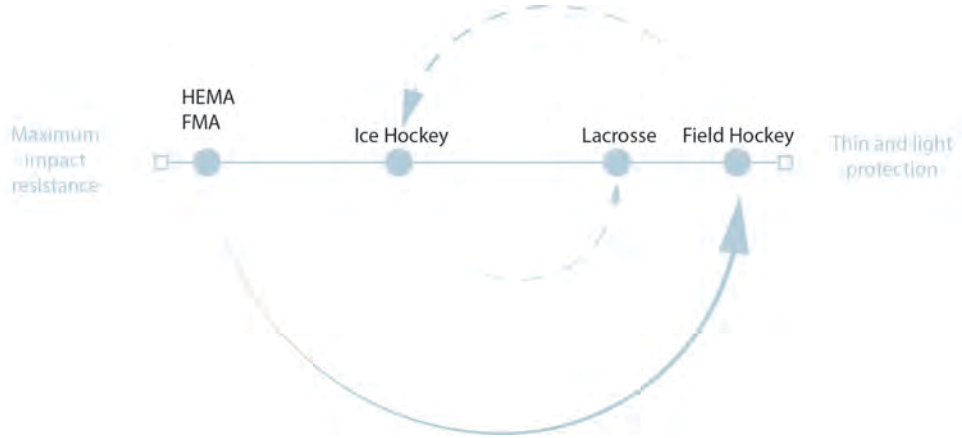


LEARNING FROM REDESIGNS

For field hockey, CrossGuard will need to develop a thin, light and well-ventilating glove that offers better protection than the competition. In a way, this can be seen as the two ends of a spectrum, as shown in the figure below. If CrossGuard succeeds in designing such a glove, this knowledge can be used to develop other redesigns, for activities that fall somewhere in field hockey and HEMA on the scale of protection vs. slim design.

These activities could be ice hockey and lacrosse, for example. These were discarded after the user research, but that doesn't necessarily mean that CrossGuard can't try to enter those markets in the future. They were discarded because they aren't attractive for CrossGuard at this point in time, but that might change in the future, if they have developed more than one type of glove.

Ice hockey gloves are a bit more rugged and less flexible than lacrosse gloves, so this is probably the easier of the two to design first. Lacrosse gloves are highly specific, since the hands are used in many different positions.



Brand architecture

Launch a new hockey brand vs. partnering with an existing brand

- Considering the potential future scenarios for CrossGuard, it would be advisable to enter the hockey market as an individual brand, instead of partnering with an existing brand.
- Partnering with another brand, this may dilute the strong differentiation of the hockey glove. Unless it's completely unfeasible financially, it would be advisable to introduce the hockey glove as a new brand.
- A financial analysis will be needed to determine the feasibility of creating a new brand.
- CrossGuard will need to move fast and produce many gloves quickly to keep the first mover advantage.

Brand extension vs. sub brand

The only clear argument in favor of introducing the hockey glove as a brand extension is that it is cheaper and more convenient in terms of resources. Other than that, it would be unwise to do a brand extension, as it will likely lead to customer confusion. Not only in the hockey market, but also in the HEMA market.

Building and preserving brand authenticity

The hockey market is much larger than the HEMA market, so for HEMA practitioners it may come across like CrossGuard is departing from their original intentions and motivations and is going for a more lucrative market. They may then feel left behind by CrossGuard. This may lead to a decline in brand authenticity [30].

- Brand authenticity is one of the most important factors for consumers to choose a certain brand. This applies to the general population, but is especially true for millennials [31, 32].

For the hockey market, it is the other way around. If it becomes too apparent that CrossGuard originally has nothing to do with hockey whatsoever, this might make consumers question the values of the brand.

- In short, the two markets are so far apart that it would be advisable to create a separate brand for the field hockey market. This would benefit the brand authenticity and limits customer confusion.

Branded house vs. house of brands

If CrossGuard has different products in different markets, it is important to consider the relationship between these products. Are they actually the same kind of thing in a different context, or are they vastly different? Do associations with another other context improve or degrade the credibility of the brand in the given markets?

In defining the brand architecture, CrossGuard will need to take such considerations into account.

The two general directions here are a "branded house" and a "house of brands", as described in the book *Brand Management: Co-creating Meaningful Brands* by Michael Beverland [30]. The main difference between these two brand architecture models is the point of focus of the brand.

BRANDED HOUSE

In a branded house, the (parent) company is the source of identification [30]. One of the most famous examples is Google. They offer a wide variety of services, e.g. a search engine, navigation, a mobile operating system, autonomous vehicle technology and much more. These brands are all connected by the same overarching brand identity.

HOUSE OF BRANDS

In a house of brands, the parent company is mostly invisible. The visible brand is that of the products themselves. One of the most famous examples is Unilever, where the large range of brands don't seem to be connected at first sight.

HYBRID MODELS

A combination of the two. This can have various forms.

Recommendation: house of brands

Field hockey and HEMA have little or nothing to do with each other. The audience, lifestyle, demographics, needs and wishes are worlds apart. None of the interviewed players knew what HEMA was, and after learning about it they said that they did not see it as an advantage that the glove was designed by a HEMA brand. In terms of protection, relating it to the HEMA context might add some credibility, but the two sports are so far apart in everything else that it would be more logical to keep the brands separated.

In the future CrossGuard could move towards a hybrid brand architecture that also incorporates a branded house strategy, depending on their product portfolio. For instance, If CrossGuard also decides to develop other types of protection in certain markets, e.g. foot protection for field hockey.

8. Conclusions & recommendations

Conclusions

During this project, the opportunities for CrossGuard expand into a different market were explored.

The initial aim of this project was to determine if the ProGauntlet can be sold in another market besides the HEMA market, with minimal design changes, preferably none at all.

The process has consisted of an analysis of the ProGauntlet, literature research into potential markets. These have been narrowed down to six interesting markets: Kendo, Filipino Martial Arts (FMA), field hockey, ice hockey, lacrosse and motorcycle riding. User research has been conducted in these markets to determine if the ProGauntlet or parts of it would be useful for these situations.

Throughout the process it has become clear that there is no viable follow-up market for the ProGauntlet. Its highly HEMA-specific design makes it an unlikely alternative in any other use case.

The ProGauntlet can resist repeated hard impacts better than any other articulating, flexible glove on the market. Sadly, this alone does not make it useful for any other activity that has been researched. In many cases, impact protection is a favorable quality, but other aspects like dexterity, size and weight are often equally important.

The realistic use cases for the ProGauntlet seem to be limited to armed martial arts with metal swords. This includes HEMA and a very small niche of FMA. The glove will most definitely will need to be redesigned for any other type of use.

FILIPINO MARTIAL ARTS

Atienza Kali is is a niche of the Filipino Martial Arts market, where people use metal blades and engage in full-contact combat. These people are likely the only FMA practitioners who would actually be willing to buy the ProGauntlet, as they are the only known FMA system that would clearly benefit from it. This group consists of about 500 people, mostly located in the USA. These people already buy their equipment through the exact same reseller as CrossGuard already has in the USA, so there is no need to change anything in terms of sales channels. This group would be a nice addition to the total market for the ProGauntlet, but it is too small to justify any design adjustments.

REDESIGN

Over the course of the project, CrossGuard has reconsidered their view on making redesign. In part due to the research done during this project, they have seen that a redesign is necessary for any other market.

FIELD HOCKEY

When considering a redesigned glove, the needs in field hockey align with the defining qualities of such a glove. Solving the problems with the current gloves seems to be something that is within the reach of CrossGuard's capabilities. There are a high number of hand injuries in field hockey and there is a lot of room for improvement in the gloves department, looking at the designs of current gloves. There appears to be plenty of interest in a field hockey glove that effectively solves the current problems.

BRANDING STRATEGY

The next step was to determine a branding strategy for the market of choice. Therefore, the field hockey market has been analyzed further and and initial direction for a branding strategy has been proposed.

The recommended positioning of a glove in the field hockey market is based on a bipolarity: "***unrestrained protection***". This positioning essentially reframes the hockey glove as a performance aid, instead of a restrictive, limiting piece of protection. With unrestrained

protection, the user can even perform their activity even better *thanks to* the protection that they are wearing.

"Unrestrained protection" may sound very similar to CrossGuard's current slogan: "protection without compromise". However, the meaning is different in an important way:

Unrestrained protection carries the meaning of "enabling ultimate performance", whereas protection *without compromise* can be described as "not limiting performance".

THE FUTURE

An additional argument for positioning the products as Unrestrained Protection, is that the concept can be applied to the entire brand of CrossGuard, and gives a clear direction for other products in the future as well.

Limitations of this study

The main purpose of this report is to describe which markets CrossGuard should focus on. In practice however, a lot (if not most) of the time is actually spent on finding out what they should *not* focus on. Perhaps some outcomes might come across as logical in hindsight, the outcome has definitely not always been as clear during the process. The outcomes of this project is the result of an thorough investigation into many different activities, statistics like injury data, and user research.

Great efforts have been made to ensure that the so-called "blind spots" in the research are as little as possible. Despite these efforts, there will nevertheless always be some blind spots, since there are some things that we simply cannot know with complete certainty.

Despite the best intentions and thorough analysis done during this project, there is always a chance that something has been missed, or that there are paths left unexplored.

Discussion

During this project, it became apparent relatively quickly that the ProGauntlet in its current shape was not going to be very useful in another market. Nevertheless, the search for new opportunities for CrossGuard kept on going. In the end, the field hockey market turned out to be a very plausible market for CrossGuard, but the whole process did raise a thought: maybe there just isn't always a good solution for everything. In many of the researched activities, a ProGauntlet-esque glove just wasn't the most logical solution to the problem.

The situation can be described quite simply: CrossGuard has designed the ultimate HEMA glove, but as the HEMA market is relatively small, they want to make the ProGauntlet useful for other purposes, too. This might not sound too strange, but it is actually comparable to examples in history.

One of the most famous examples of this is Watson, the AI developed by IBM. In 2011, the world watched in amazement how Watson won against real people at *Jeopardy!*. Right afterwards, IBM decided to use this power to revolutionize the healthcare system. AI doctors would change everyone's lives. Sadly, Watson did not revolutionize healthcare. It did not prove to be as useful in reality as was anticipated, and was more or less degraded to an automated doctors' assistant[3].

How could this happen?

[3] https://spectrum.ieee.org/biomedical/diagnostics/how-ibm-watson-overpromised-and-underdelivered-on-ai-health-care

In short, IBM started with a very specific use case, then invented a super high-tech solution for it, and then started wondering how it could actually be useful[4].

This is similar to the problem that CrossGuard has: a technological solution that is looking for a problem to solve. Luckily, CrossGuard's problem is multiple orders of magnitude smaller than it was for IBM.

In this situation CrossGuard has the advantage of being a small company, which makes it much easier to change its course. With a redesigned glove and the philosophy of unrestrained protection, CrossGuard likely has many opportunities to expand into different markets and contexts in the future.

[4] In reality, it is a bit more nuanced of course, but this does appear to be one of the underlying causes.

Recommendations for further research

Financial analysis of the brand strategy

In this report, a recommendation is made about whether CrossGuard should introduce the product independently or if they should collaborate with an existing brand. This recommendation has been made from a product design and branding perspective. The financial implications of this will need to be researched, to assess the feasibility of it.

- Evaluate the case for penalty corner gloves, taking into account that only the elite teams actually have enough pairs of gloves.

RESEARCHING OTHER MARKETS FOR A REDESIGN

- Using the technology of the glove for other sports or in combination with existing glove designs, for e.g. construction.
  - The initial purpose of this project was to find out if the ProGauntlet can be introduced in a different market and how to realize this. This process led to the FMA market. When looking at the type of protection the glove offers vs. what is needed, the field hockey market appears to be a logical next step. Nevertheless, there might still be chances for CrossGuard in the PPE market, which is growing[5]. Such a glove will likely be vastly different from the ProGauntlet. For this project, the differences were too great to justify this market, but it might be interesting in the future.
  - The role of unrestrained protection in construction: how can it help people in doing their work safer and better?

[5] https://www.fortunebusinessinsights.com/personal-protective-equipment-ppe-market-102015

Next steps

NEXT STEPS IN THE HOCKEY MARKET

- Launch strategy
  - Promotion
  - Customer journeys and touch points

CROSSGUARD AS A BRAND

Reconsider the name, since “CrossGuard” is quite specific to sword-based martial arts

UNRESTRAINED PROTECTION ACROSS MULTIPLE MARKETS

If CrossGuard manages to succeed in multiple markets, they might want to consider a different brand architecture, namely a branded house. This strategy will likely become more attractive if they want to take “unrestrained protection” into as many markets as possible.

For now it will still probably make more sense to start as a house of brands in the field hockey market.

(RE)CONSIDER BUSINESS MODEL

At this moment, CrossGuard is more a design company than a production company, in terms of interests and production scale. If CrossGuard would want to enter different markets in the future, they can also consider to become a design company for clients that want unrestrained protection for their specific context.

9. Personal reflection

Personal reflection

This thesis is the final result of almost half a year of hard work.

By completing this, I'm also completing my time at university. It feels strange, especially in these weird times of working from home, to finish that chapter of my life. But the time has come to move on, to trade the university life for whatever comes now.

The image shown above is perhaps one of the most concrete effects of my hard work over the last months during this graduation project. The paint on my keyboard keys is starting to come off, likely due to the vast amount of typing this project has involved, in combination my somewhat hard, hammering way of typing.

The project

The project was very interesting in many ways. During the research I have learned a lot about subjects that I would never have thought of myself and also learned a lot about the ways of working at or together with a startup.

BEING TAKEN SERIOUSLY

What I highly appreciated, was that CrossGuard allowed me to be actively involved in their meetings with the people in the field hockey market, including meetings with national teams. This made the effects of my work feel very real. It was very valuable for my project and it also gave me a sense of recognition, since I was being taken seriously.

OUTCOMES

- It is nice to see that the company is really designing a field hockey glove, in part thanks to my research.
- I am surprised by the outcome of this project. I hadn't anticipated that the field hockey market would really be the next market for CrossGuard. This does have to do with the original project brief, though.

AMBITIOUS

One comment that I would have on the project is that it might have been a bit (too) ambitious. The project consisted of many different stages, many different research directions and multiple outcomes. It. Often felt like a bit too much, especially near the end of the project. I often felt as if I should be doing more and should be working even harder, even though I was already doing the best I could.

I can confidently say that I have done what I could in the given time frame.

BRANDING

With a branding strategy, there's always more to do: you can always take it a step further. I had great difficulties with setting boundaries for myself in the process. I wanted to do it all, which in the end resulted in spending lots of time on things that weren't relevant for the report. In the end, wanting to do everything perfect often even leads to producing less of the things that really matter. I feel like this is the case with the branding section. It feels as if I could have taken it a step further, even though I know that I have spent all the time and effort on it that I was capable of. I guess that you just sometimes need to accept that not everything always works out as planned.

Despite this, I am happy with the positioning that I have defined for CrossGuard, and they also appear to be positive about it. What I like

about it, is that just two words can explain so much for a company. I think that this is the case with “unrestrained protection”.

COVID-19

VIDEO INTERVIEWS

As anything, this project was affected by COVID-19 in some ways. Most of the effects weren’t very pleasant, like working at home all the time, being alone and not being able to have a casual chat with someone you meet at the coffee machine. However, one of the effects that was quite positive of this whole situation is the sudden normalcy of video calls and interviews. This made is much more accessible to interview people in the USA, for instance. As most people work from home now, it was also relatively easy to schedule interviews with most people.

One of the main difficulties that I experienced was that I had little or no frame of reference around me: I had no clue if I was doing well or not during the process, as I couldn’t really find people in a similar situation around me to talk to. I often struggled with seemingly simple tasks, as asking help is more difficult when working from home, and this became increasingly difficult the deeper I went into the process.

SEPARATED FROM THE COMPANY

Even though I had a weekly call with the company mentor, I sometimes felt a bit isolated from the company. Sometimes, in extreme cases, it wouldn’t even feel like I was doing a real project. The meetings that I had with the company and the visible effects of my work in the design of the hockey glove helped a lot in overcoming this feeling of separation.

Process

REPORTING

For me, the “academic” side of the project was actually one of the most difficult parts. With this I mainly refer to the reporting and planning. This cost me a great amount of time and energy, especially the reporting. The process often felt like a sort of jigsaw puzzle that only fits together all at once, instead of piece by piece. This made it difficult to finish a lot of things until the very last moment, as many parts of the report are dependent on each other.

Working “ambidextrously” during this project proved to be difficult: improving the reporting of the work done, while working on new things at the same time. I often got. Stuck on one of the two, and then forgot about the other one. I do think that I have improved in this during this project.

DESIGN METHODS

In the process, I did notice that design methods do help. In a few cases where I felt stuck or lost, some methods could help with structuring my thoughts

STRESSFUL

To be honest, I have experienced the last five and a half months as quite stressful. Despite this stress (or thanks to it) I have learned a lot about myself and my way of working during this project.

To use an analogy, I would compare my way of working to a slingshot. At the start of the project I zoom out to get an overview, but this also builds up pressure. Usually, near deadlines, I manage to work with an extreme focus, and then go all out to reach my goals. With too much pressure however, the figurative elastic bands, or my attention span become overstretched and then it becomes harder to pick up the work after every deadline. If this happens too long and

too often, it can lead to a total blocking up. During this project I noticed that I was approaching that point increasingly closely.

Changed project brief

At first I was a bit frustrated that the focus of the project brief had changed so late in the process, as I had done my research in a certain way to answer the question in the original brief: finding a market for the ProGauntlet with minimal or no design changes.

After this initial frustration I actually noticed that it was a good thing that the project brief had changed. The change in CrossGuard's standpoint had been largely due to my research, so this was actually one of the greatest achievements I could possibly have made during this project.

I had feared that my prior research would be irrelevant and that I would have to more or less start over. Luckily I discovered that this wasn't true. As I had done the initial market research from a user perspective, I knew about the main problems in those markets regarding hand protection as a whole. I was trying to match the qualities of the ProGauntlet with the needs of the market. If those needs and qualities aligned well enough, I kept on researching those markets, in order to find opportunities.

Learning goals

In my project brief, I had defined a number of learning goals:

SPREADING MY WORK EVENLY

Planning long ahead and then actually following that plan has never been my strong suit. During this project, it think that I have succeeded relatively well in this.

My focus is always very much "on" or "off". I'm either hyper-focused on the project or task at hand, or have great difficulties in getting anything done at all. Managing this during such a large project has been very challenging, but I have learned a lot in the process and I think that I have succeeded quite well.

I had planned to write daily and weekly reflections throughout the project. I did do this in the beginning, but I stopped after 20 days or so. In that period there was little to write for each day, as I was mainly working on the literature research. Many days felt more or less the same, so reflecting felt a bit pointless then. After that, I didn't really pick it up again.

The main purpose of these reflections would be to keep track of my process and progress. I did write down some personal notes throughout the process, so I think that I did still capture an important part of those thoughts.

MAKING CHOICES SOONER

Another goal was to make choices sooner, instead of postponing them to the last possible moment. For this, I intended to use the Pomodoro technique. This involves setting an alarm every 25 minutes, and to have a short break between sessions. I did this throughout the entire project fairly consistently. This was something that was easier to do when working from home. The technique helped me in working more focused and spending less time procrastinating, but it did not necessarily help to make decisions sooner. Personal deadlines, such as finishing a certain section before a certain time of the day, are difficult to keep when working alone. I'm still searching for a better method for this.

LEARN HOW TO WORK IN A STARTUP ENVIRONMENT

Due to COVID-19, I spent most of my time working from home. Therefore it was a bit more difficult to experience working in a startup environment. Nevertheless, I think that I have still learned a lot about the startup/small company ways of working and interacting through the meetings that I had and through the time that I did spend at the office. I liked a lot of things about it: direct, informal contact with people, autonomy and seeing that your work really matters. I will definitely take these elements into account in looking for the next steps after my graduation.

10. Appendix

Appendix 1: Project Brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

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

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

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

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

family name: Bouwers
initials: DT given name: Douwe
student number: 4303032
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ( ) IPD ( ) Dfl (X) SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ( ) Honours Programme Master
specialisation / annotation: ( ) Medisign ( ) Tech. in Sustainable Design ( ) Entrepeneurship

SUPERVISORY TEAM **

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

** chair: Erik-Jan Hultink dept. / section: PIM / MCR
** mentor: Pinar Cankurtaran dept. / section: PIM / MCR
2nd mentor: Arnaud van der Veen
organisation: CrossGuard
city: Delft country: The Netherlands

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

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

comments (optional): During this project I will be focusing on positioning the ProGauntlet in a different market. Developing the marketing strategy and the branding of the product are Pinar Cankurtaran's areas of expertise, whereas Erik-Jan Hultink is an expert on launch strategies and innovation management. These areas of expertise combined, I believe that the most important parts of the scope of the project are covered.

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

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair _____ date ____-____-____ signature _____

CHECK STUDY PROGRESS

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

Master electives no. of EC accumulated in total: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name _____ date ____-____-____ signature _____

FORMAL APPROVAL GRADUATION PROJECT

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

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

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name _____ date ____-____-____ signature _____

Initials & Name DT Bouwers Student number 4303032

Title of Project Mapping the future of protective hand-exoskeletons: Market identification and branding strategy development

Personal Project Brief - IDE Master Graduation

Mapping the future of protective hand-exoskeletons:
Market identification and branding strategy development

project title

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

start date **06 - 07 - 2020** **4 - 12 - 2020** end date

INTRODUCTION **

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

I will be doing this project in collaboration with CrossGuard, which is a company that produces protective gloves. These gloves are called the ProGauntlet and they work like an exoskeleton that protect the hands without restricting the freedom of movement. The ProGauntlet has been designed to offer an extremely high grade of impact protection that doesn't deteriorate over the lifespan of the product.

The ProGauntlet is designed for people who practice Historical European Martial Arts (HEMA), double-handed sword fighting in particular. It has been designed to withstand high-impact blows from metal swords repeatedly, to protect the users' hands from virtually any type of impact caused by the these swords. Without adequate hand protection, these blows would easily cause bruises, cuts and/or fractures in the hands of the users. The founders of CrossGuard are firmly grounded in the world of HEMA, which explains their choice to launch the ProGauntlet in this market first.

CrossGuard is the main stakeholder during this project. The company needs to find a way to sell more ProGauntlet gloves, as they have been developing the gloves for about six years now and need to start generating a profit. They are shipping their first batch of pre-orders at this moment.

space available for images / figures on next page

introduction (continued): space for images

image / figure 1: A pair of ProGauntlet gloves

image / figure 2: Exploded view of all components of the ProGauntlet

Initials & Name DT Bouwers Student number 4303032

Title of Project Mapping the future of protective hand-exoskeletons: Market identification and branding strategy development

PROBLEM DEFINITION **

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

The ProGauntlet likely has a huge potential in other markets where hand protection and freedom of movement are necessary. Potential markets that come to mind include e.g. construction, field hockey and military use. During my graduation project I'm planning to determine the next market(s) in which CrossGuard should launch the ProGauntlet.

CrossGuard is highly interested in this type of research; they even called it "essential to the future of the company". CrossGuard estimates that the size of the HEMA market is about 65,000 users worldwide. According to CrossGuard this market is large enough for the company to continue in its current form, but the total number of users of the ProGauntlet will need to increase if the company wants to grow. This can be done in multiple ways, so during this project I'll focus on increasing the total number of users by exploring other markets to venture into.

As CrossGuard has invested a lot of resources into the current design and production process of the ProGauntlet, the company has made clear that the technical changes in the design should be kept to an absolute minimum, preferably none at all. Therefore I will only propose a redesign if certain changes to the current design are essential to sell the gloves in a different context. Minor esthetic changes such as the color and finish of the product can be done if this is necessary for the given context. Bigger changes should only be considered if this can be justified by a large market size and return on investment.

ASSIGNMENT **

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

I am going to determine the next steps CrossGuard should take in order to maximize the total number of gloves being sold. The ProGauntlet likely has great value for users in different markets who need a protective exoskeleton around their hands. At this moment however, it isn't clear in which market(s) this would be the case. Finding a market of which the (latent) needs meet the characteristics that the glove has to offer will be the main focus of my research, in order to design a market development strategy (Ansoff, 1957). To develop this strategy, I will conduct mainly qualitative research: I will interview industry experts in the fields of hand injuries and hand protection, as well as experts in the potential markets that I will define during the first stage of my process. To uncover latent needs of potential users, I will also conduct generative research, with at least one interactive session. In the event that market development alone isn't a viable option for CrossGuard, I will look into design changes that are needed for diversification (Ansoff, 1957).

The output of this project will consist of two parts:

1. **A clearly defined next market for the ProGauntlet.** I will deliver the following to explain this:
- A comprehensive report, containing the results of my market research and consumer research.
- A roadmap that helps CrossGuard to grasp and realize the future vision for introducing the ProGauntlet in other markets than the HEMA market.

2. **A branding strategy for introducing the ProGauntlet in the next market.** This will consist of:
- A brand identity, including the rationale behind this identity, the supporting research and documentation.
- A visual style guide.
- A launch strategy for entering the next market.

Ansoff, H. I. (1957). Strategies for diversification. Harvard business review, 35(5), 113-124.

PLANNING AND APPROACH **

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

start date 06 - 07 - 2020 — 04 - 12 - 2020 end date

Graduation Project Planning overview

		Project week	-1	0	1	2	3	4	5	6			7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Calendar week	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
		Date (Monday of each week)	Jun 22	Jun 29	Jul 6	Jul 13	Jul 20	Jul 27	Aug 3	Aug 10	Aug 17	Aug 24	Aug 31	Sep 7	Sep 14	Sep 21	Sep 28	Oct 5	Oct 12	Oct 19	Oct 26	Nov 2	Nov 9	Nov 16	Nov 23	Nov 30
		Project day (start of week)	-10	-5	0	5	10	15	20	25			30	35	40	45	50	55	60	65	70	75	80	85	90	95
Kickoff meeting																										
Midterm meeting															Sep 17											
Green light meeting																										
Final Presentation																										
Write Project brief																										
Background research	Research hand protection																									
	Research current competitors																									
	Review research already done by CrossGuard																									
Define other markets that need hand protection	Literature																									
	Contact experts on hand injuries																									
	Write literature section																									
	Prepare generative research																									
	Generative research, host a brainstorm session at CrossGuard, with "homework" for participants																									
	2nd generative session, analyze results																									
Explore the potential markets that I have already defined	Sports	Armed Martial Arts (AMA)	Literature		Write literature section	Prepare interviews	Qualitative Research: Interviews		Analyze data		Holiday (15-08-30-08)		Validation													
		High-risk ball and stick sports																								
		Downhill extreme sports																								
		Motorsports																								
		VR gaming		Literature																						
		Re-enactment																								
	Industry	Construction																								
	Military & Law Enforcement	Police																								
		Armed Forces																								
	Corporate	Insurance companies																								
Narrow down potential markets	Dismiss unlikely markets																									
	Map the size of the potential markets																									
	Dismiss small markets																									
	Discuss options with CrossGuard																									
Roadmapping	Develop product vision																									
	Define horizons																									
	Time pacing strategy																									
	Visualize roadmap																									
	Update roadmap based on redesign																									
Branding	Competitor analysis																									
	Review brand identity																									
	Define new brand: name, DNA & rationale																									
	Develop brand manifestations																									
	Write & draw plan for video																									
	Shoot and edit video																									
Finishing touches, reporting & presenting	Finish report																									
	Prepare final presentation																									
	Final presentation																									

Initials & Name DT Bouwers Student number 4303032

Title of Project Mapping the future of protective hand-exoskeletons: Market identification and branding strategy development

MOTIVATION AND PERSONAL AMBITIONS

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

What I like about this project is that it involves a product that appeals to many people, but of which the exact purpose isn't clear straight away. The ProGauntlet is without doubt a great product in a technical sense, but its real-life use needs to be reassessed to get the most out of it. I'm excited to search for the problem that matches this solution.

Earlier this year I have briefly done an internship at a consultancy firm. It's safe to say that this has completely overturned the way I look at my future career and goals. I discovered that I did not like a lot of things that I always thought I would value in my job. I was exhausted at the end of every single day, without feeling that I had done anything particularly useful or meaningful. I personally think that a lot of time was lost on ineffective communication and a lack of clearly defined goals. On top of this, I often felt like the quality of my work was all the same to the company, meaning that it actually paid off to produce a lot of mediocre work that was well below my own standards, instead of spending a bit more time and effort on creating high-quality work. This experience has made me rethink a lot of my professional ambitions. I think that this project for CrossGuard will be the polar opposite to this experience in many ways. The main focus of the company is clear: they have designed a single product and it needs to be sold now. The work environment is informal and goal-oriented, and the outcome of my project is extremely meaningful for CrossGuard. This motivates me to work towards the best possible result for everyone. During this project I also want to find out if I indeed enjoy working in a startup environment like this.

General personal ambitions

1. **Spreading my work evenly.** Over the course of my studies at the TU Delft, I have tried many different methods to achieve this, with mixed results. I see my graduation project as an opportunity to optimize my own structure and working style. Handling distractions is one of the main challenges. One of my most important discoveries in tackling this has been that my breaks are just as important for my productivity as my "real" working time. Working in short sprints makes it more manageable to resist distractions and at the same time it works as a way of limiting the time I spend on one task. Taking frequent short breaks also allows me to keep an overview of my entire process and it also allows me to assess if what I'm working on is relevant or not. To make sure I keep on taking frequent breaks, I use the Pomodoro technique. I intend to use this or a similar technique throughout my entire project to stay focused, motivated and productive. To keep track of my progress in this regard, I intend to keep a diary in which I describe my productivity, methods and achievements for every single day. I will update this diary at the end of each working day.
2. **Making choices sooner.** This project has many different possible approaches, and I have to make sure that I don't get stuck on analyzing and philosophizing about the possibilities. I think that the "fail fast" philosophy of the agile approach applies here. Recognizing your own mistakes and then starting over is often more effective than endlessly thinking about the possibilities. Methods such as setting alarms to remind myself of daily deadlines helps to prevent me from lingering on decisions for too long. During this project I will be keeping a log book to keep track of my decisions as much as possible.
3. **Learn how to work in a startup environment.** I have no prior experience with working for a startup, so I want to find out if it works for me. I know that it can be uncertain and hectic, but I generally get more motivated if I know that my work matters. I intend to keep track of my thoughts on this topic by writing a weekly reflection.

FINAL COMMENTS

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

Appendix 2: Literature research findings

Introduction

The ProGauntlet has been designed to prevent hand injuries during HEMA. Since injury prevention is the most important quality of the ProGauntlet, it makes sense to analyze in which other situations hand injuries occur and to assess whether the ProGauntlet might prevent these effectively.

Statistics on subjects such as hand injuries are a good starting point for further research, but statistics alone don't give the full image of a certain context. The potential usefulness and value of the ProGauntlet is dependent on many more factors. Some of these factors can be evaluated through literature research, but user research and testing are also essential factors in assessing the viability of the ProGauntlet a different market. How the glove might be used in practice, what people like about it and what should be changed (if necessary) are examples of factors that can't be judged from literature research alone.

The main goal of this literature section is to make an initial selection of potentially attractive markets for the ProGauntlet, by analyzing the current causes and types of hand injuries and current solutions if applicable. This process involves both diverging and converging. First, a general overview should be made of hand injuries in general, in order to define and subsequently zoom in on the activities of interest.

DEMOGRAPHICS

The estimated proportion of hand injuries compared to the total number of injuries in general varies between different studies. One study on hand injuries that required hospital treatment, claims that up to 28% of all injuries are related to the hands [8]. Unlike most other injuries, the gender ratio of hand injuries is not equal between men and women. Men sustain over three times as many hand injuries as women [14]. In the USA, the treatment costs of upper extremity injuries, including hand injuries exceeds 18 billion US dollars each year [33].

Such numbers suggest that there is a lot of room for improvement.

CAUSES OF HAND INJURIES

When looking for the next potential markets for the ProGauntlet, it is important to determine in which situations the glove can have a positive impact. One way to uncover these situations is to analyze common causes of hand injuries.

Almost half of all hand injuries happen at home and about one-fifth happen while at work, but the injuries at work are often more severe [8]. Generally speaking, most injuries occur amongst men under the age of 40, and especially amongst those whose jobs mainly consist of physical work. This is the case for injuries in general, as well as for hand injuries specifically [8, 13]. Therefore, it seems to be worthwhile to take a closer look at the available literature about these hand injuries.

COMMON TYPES OF HAND INJURIES

Two of the most common types of hand injuries are fractured metacarpals and fractured phalanges [10]. The metacarpals are the bones on the back of the hand, and are the largest bones in the hand. Phalanges are the bones in the fingers: there are three for each finger and two for each thumb. Between 10% and 25% of these injures happen during sports [10, 15].

Most of metacarpal fractures happen among the younger population, between ages 15 and 24. Over three quarters of these

metacarpal fractures happen among men, mainly by impact on the fist, while punching a hard object. Sports are the second most common cause, and within this category, contact sports like American football are the main cause of injuries [11, 12].

The ProGauntlet mainly protects the outside of the hand against blunt impact, which coincidentally is also the main cause of fractured metacarpals [9].

DIRECTIONS FOR LITERATURE RESEARCH

Unfortunately, the ProGauntlet cannot prevent all types and causes of hand injuries. It is important to separate the scenarios in which the ProGauntlet can be useful from those in which it won't as quickly as possible. For instance, one of the causes of hand injuries that we can discard for the purposes of this research, is alcohol consumption. Despite the fact that according to one paper, a quarter of all hand injuries happen after the consumption of alcohol [8], It can be assumed that the ProGauntlet won't prevent any of these injuries from occurring, unless users would wear the ProGauntlet to bars and such (which would potentially open up a whole other set of problems). Therefore alcohol-related injuries will not be further investigated in this report.

The five main research categories in this section are:

1. Armed martial arts
2. Occupational hand injuries
3. Military and law enforcement
4. High-risk bat-and-stick sports
5. Motor and bike sports

The initial aim of the literature research is to get a general idea of the chances for the ProGauntlet in each of these categories. If the literature suggests that there are unresolved causes of hand injuries in any of these categories, then a further investigation into activities within these categories is done to determine potentially interesting markets.

2.1 Armed Martial Arts

The ProGauntlet has been designed for Historical European Martial Arts. This is a highly specific context with its own unique set of requirements, user needs and wishes, all of which have influenced the design.

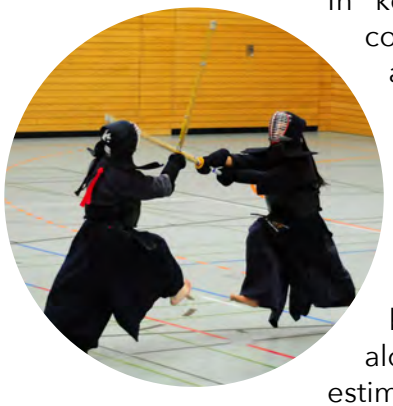
As a sport, HEMA is part of the category of Armed Martial Arts (AMA). Therefore it makes sense to look at other Armed Martial Arts, to find out if the needs in these sports align with the qualities of the ProGauntlet.

The two types of AMA that are researched are called Kendo and Filipino Martial Arts. These two sports were suggested as potential markets by one of the founders of CrossGuard and they are two of the largest sports in the AMA context.

The injury profile of HEMA is different from other armed martial arts. The use of the sword is somewhat similar to kendo, but certain grappling techniques are also allowed, making it similar to judo and sumo wrestling in some ways [3]. The types of hand protection that have been used up until now either don't offer enough protection, or limit the freedom of movement too much. In both cases, the performance and safety are impacted negatively. The ProGauntlet appears to solve the problem very effectively by offering full protection and almost unrestricted freedom of movement at the same time. According to the people at CrossGuard, the ProGauntlet allows HEMA practitioners to use other techniques that are either too

dangerous or physically impossible with other gloves. This allows the players to mimic the techniques that were originally used for medieval sword fighting more closely.

2.1.1 Kendo



In kendo, hand and wrist injuries are more common among elite players than among amateur level players. A likely explanation for this is that highly skilled players are better at aiming for the wrist, which counts as one of the strike-zones in kendo [34]

Estimations of size of the worldwide population of kendo players vary, ranging between 1.66 and 1.8 million people in Japan alone [34, 35]. The worldwide population is estimated be somewhere between 2.8 and 6 million people [35]. In the last half century, kendo has become increasingly popular inside and outside Japan, and the sport is currently practiced in over 70 countries. [34]. As a result of the aging population in Japan, caused by low birth rates, a lot of local dojos and clubs will have to close in the future [35]. Despite this, the worldwide kendo population is still growing.

Kendo is firmly rooted in Japanese traditions and many kendo players from outside Japan start practicing the sport out of interest in the Japanese culture. [36]. This might mean that the community can be reluctant to accept changes and to adopt new innovations. Literature suggests, however, that players are considering the use of smart technologies during training, such as wearable strike recognition devices [37] and headgear that measures response time [38]. This could indicate that the community is open to accept innovations if this benefits their kendo performance. This would be a good sign for the potential adoption of the ProGauntlet as a kendo glove.

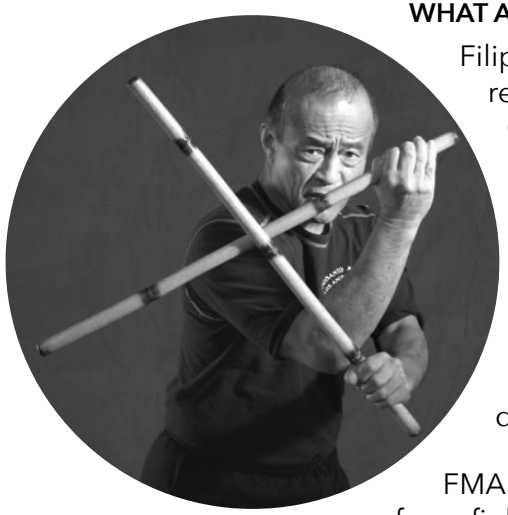
Kendo practitioners, known as *kendoka*, use bamboo swords to fight their opponents. The kendoka are only allowed to aim their strikes and thrusts at four target areas. These are the head, the wrists, the chest and the neck [34]. As the wrists are one of the main target areas, players are highly likely to receive blows from their opponents on their hands and wrists. The ProGauntlet could prove to be a valuable addition to the kendo outfit. This would need to be validated in further research, including interviews and user tests.

Even though Kendoka wear full-body protection, injuries are still relatively common. Many of these injuries are overuse and stress injuries, due to the sudden, explosive movements that the sport involves [34]. Regarding hand and wrist injuries, wrist injuries caused by this aforementioned repetitive stress are the most common type of injury.

Impact-related injuries such as fractured fingers are less common among kendoka, compared to other martial arts, likely thanks to the protection [39]. The owner of a large kendo dojo in the Netherlands confirmed that he rarely sees hand and wrist injuries due to the protective gear of the players.

Even if hand injuries are not very common, the ProGauntlet could still prove to be useful for kendo if it enables the users to perform better by giving them a more natural sword feeling and better freedom of movement. Therefore it seems worthwhile to interview more kendoka about the use of their hands, to find out if the ProGauntlet might be able to improve their playing abilities.

2.1.2 Filipino Martial Arts



WHAT ARE FILIPINO MARTIAL ARTS?

Filipino Martial Arts (FMA) are often referred to as Kali in the western world. Other common names are Arnis and Eskrima/Escrima. For the purposes of this report, the term "FMA" will be used to describe the sport. FMA is very much focused on the possibility of using the fighting techniques in real life, so the techniques are mainly taught from a defensive perspective [40].

FMA focuses on the ability to transition from fighting with weapons to empty hands fluidly. A wide variety of techniques are used and taught, drawing inspiration from many different martial arts. A technical aspect that differentiates FMA from other martial arts, is that the free hand, which is not holding a weapon, has a dominant role. Grappling and locking techniques are examples of this [41].

There are many different systems through which FMA is taught, with each system focusing on slightly different aspects of the sport. The type of weapons, exact techniques and fighting scenarios can differ between systems, but in general FMA practitioners learn to fight with weapons before transitioning to unarmed combat. This is due to the notion that the technique of unarmed combat is similar to that of armed combat, but it takes more skill to execute properly [41].

MARKET SIZE

The (very limited amount of) available literature doesn't clearly state the size of the worldwide FMA population. According to CrossGuard, who have made a rough estimation of the total market size, there are about 300 thousand FMA practitioners worldwide. CrossGuard has warned that this is a very rough estimation although it is based on reports from a high-level European FMA instructor.

DIFFERENT WEAPONS

Some high-level FMA practitioners focus on fighting with live weapons, without protection. This has led to many severe injuries, sometimes even fatal. Therefore this practice has now largely become illegal [41]. Due to the extreme dangers of fighting with live weapons and without protection, most practitioners wear protection, depending on their level, the type of weapons used and the type of training. Most people also use hardwood or polyester sticks instead of metal knives [40].

CONCLUSION

The ProGauntlet might be useful for FMA, as it involves a lot of different techniques and weapons, and the hands need to be protected against as many different types of impact as possible, while staying flexible. During unarmed combat however, it might pose a danger of injuring to the opponent due to the hardness of the outer shell. It nevertheless seems interesting enough for further research.

2.2 Occupational hand injuries

Literature suggests that acute hand injuries are the leading type of occupational injuries in the United States. Around a million workers are affected by occupational hand injuries yearly [42, 43]. Hand and finger injuries account for more than 23% of all reported occupational hand injuries reported in the US [44]. According to another study, finger injuries alone account for over 80% of all occupational injuries in southern China [33].

The average cost per injury for such injuries is $21,918 in the US [44]. Preventing these injuries altogether would result in the largest reduction of lost working days, compared to other causes [44]. People that sustain injuries at work generally need a longer time to return to their job than for injuries that occur outside of the workplace. This might have to do with the nature of the jobs that are prone to hand injuries [45], rather than the cause and type of injuries.

Interestingly, despite the seemingly high incidence of occupational hand injuries, relatively little research has been done on cross-industry comparisons occupational injuries, risk factors and prevention measures [43]. Many studies are highly specific about one context, but a comparison with other industries is lacking. The most comprehensive research in this field has been done by Sorock et al., who also point out that it is often difficult to compare different studies on this subject, since the definitions and contexts can differ greatly between studies [42]. Therefore the results must be interpreted with some caution. Nevertheless, the high incidence, costs and the loss of time suggest that there is a strong case to improve hand and finger safety at work.

2.2.1 Causes of occupational hand injuries - general

As mentioned before, results can differ greatly between different studies, depending on the context and the industries that are being investigated.

MACHINERY

Machinery, tools and other mechanical equipment reportedly accounts for anywhere between 35% [8] and 99.6% [13] of all occupational hand injuries, depending on the source. These studies do agree that injuries caused by machinery are both the most common and the most severe occupational hand injuries[8].

Multiple studies suggest that electric saws are the most common type of power tool that causes injuries, accounting for about half of all power tool-related injuries [13, 46]. For saw-related injuries, the thumb is the most injured part of the hand, as it is injured in 35% of the cases [47].

Whether the ProGauntlet can effectively protect the fingers against a saw blade is not fully clear. During one quick test, a spinning circular saw blade was pushed firmly against the thickest part of the wrist guard for about four seconds. The blade made a deep cut, but it didn't fully cut through the material. This indicates that the glove will likely offer some level of protection against single cases of saw blade contact, but this does permanently damage the shell.

Other, more practical solutions are already available to minimize electric saw injuries. Many modern electric saws feature flesh-sensing safety mechanisms that make the blade stop instantly if it is touched

by someone [48]. In recent years, there has reportedly been a decrease in powers saw related injuries, also partially due to stricter regulations [49].

Power tools are most often operated by the dominant hand, which results in more injuries to the non-dominant hand [43, 46]. For the ProGauntlet, this could mean that the users only wear one around their non-dominant hand. When operating table/bench saws however, both the dominant and non-dominant hands are operating in the danger zone [46], meaning that both hands need to be protected.

In another study, the authors claim that "metal items and hand tools with blades" cause most injuries [43].

HUMAN ERROR & UNSAFE BEHAVIOR

While tools and machinery are often the physical cause of many occupational hand injuries, these accidents are arguably caused by human error in many cases. Human error and unsafe behavior are regarded as leading (underlying) causes of occupational accidents [50]. For example, the same study that names electric saws as the main culprit for occupational hand injuries, suggests that this might be due to the fact that these tools can be used in various positions. This could increase the chance of operator errors [13].

Inattention, unanticipated events, inexperience are named as three major causes of serious power tool related injuries [13].

For acute, traumatic occupational hand injuries, almost all risk factors have to do with human error [42, 50, 51].

2.2.2 Types of occupational hand injuries

Cuts and punctures account for almost half (47%) of all occupational hand injuries [44]. This is true for both minor and severe injuries [42].

The outer shell of the ProGauntlet might protect against this to some extent, but the inside of the hand is very much exposed. A different inner glove could perhaps improve the situation, but the bulky outer glove isn't the most logical solution to these common problems from a design perspective. The outer shell has been designed to absorb impacts from large objects (sword blades), but not against puncturing from small, pointy objects. For instance, there are some small gaps around the joints of the outer shell, especially when the fingers are bent.

Cuts and punctures account for almost 47% of all occupational hand injuries

The causes of both light and severe occupational hand injuries appear to be similar. This suggests that cuts and punctures also account for a large portion of the severe injuries. The ProGauntlet might offer some protection against such injuries, but it's not designed for it in the first place.

2.2.3 Industries

"Occupational hand injuries" is a broad term that covers many different industries, jobs and situations. To get a clearer view on the various contexts in which many hand injuries occur, it makes sense to take a closer look at some of the industries in which hand injuries are the most common.

When looking at the total number of hand and finger injuries for each type of industry, it appears that most hand injuries happen in manufacturing, followed by construction [42]. Hand injuries are also common in the oil and gas industry [44].

MANUFACTURING

Based on a literature review of the incidence of traumatic hand injuries in manufacturing environments, the expected annual incidence ranges from 4% to 11%. [43]

CONSTRUCTION

Yearly, around US emergency departments treat close to 400,000 occupational injuries among workers in the construction industry. Of these injuries, 25% is caused by tools or other equipment, which equates almost 100,000 injuries per year. Three-quarters of these injuries are caused by hand tools (42% by powered hand tools and 33% by non-powered hand tools) [52].

Interestingly, despite the plethora of tools that are used in construction, almost two-thirds of all injuries are caused by just seven types of tools. These seven most harmful tools are knives, hammers, power saws, nail guns, drills, welding tools, and ladders, respectively [52].

OIL & GAS

In the oil & gas industries, over 60% of all injuries are hand injuries [44]. In the gas and oil industries, the risk of impact injuries is higher than in all other major industries. Pinching, crushing and puncturing are other common causes of severe injuries among gas and oil industry workers [53].

In the oil & gas industries, over 60% of all injuries are hand injuries. Impact, pinching, crushing and puncturing are common causes of severe injuries.

The violation of safety protocols appears to be one of the most common factors causing injuries in the oil and gas industry

The violation of safety protocols appears to be one of the most common factors causing injuries in the oil and gas industry [54]. This partially explains why many companies still tend to blame accidents on workers [50], instead of the procedures or other factors. In many cases, the procedures and rules are in reality inappropriate to the work being carried out, which implies a level of ignorance about the real hazards on a management level [55].

Work pressure is the most important factor that contributes to the willingness to follow safety procedures in the oil and gas industries [54]. Another important factor is the highly masculine, "macho" work culture that dominates these industries, where the workers ignore obstacles and dangers to get the job done [56].

2.2.4 Glove use

The literature does not give a conclusive answer when it comes to the effectiveness of safety gloves on injury prevention. According to one study, the use of gloves can reportedly decrease the number of injuries by as much as 60% [33].

Gloves seem to have greater protective effect among workers who haven't had any safety training [51]. Gloves can therefore function as a preventive strategy in such cases, but total prevention of hand injuries will likely require multiple interventions, such as safety training [43]. Gloves alone won't prevent all injuries from happening, if the users don't know how to work safely.

When it comes to preventing light injuries, gloves seem to have a positive impact. More severe injuries however (crushing, amputations, avulsions), likely aren't prevented by wearing safety gloves [33, 51]. In one study, over 80% of injuries occurred while people were wearing gloves [33]. These severe types of hand injuries will, most likely, also not be prevented by the ProGauntlet either.

PROTECTION VS. DEXTERITY

Making gloves more protective often comes at the expense of the dexterity and the freedom of movement of the hands. Even though the hands might be protected, this might create other dangers. A loss of dexterity can lead to dangers such as dropping objects and slipping away, if the user loses their grip. In practice, this often causes users to remove their gloves, which completely defeats the purpose of safety gloves [53].

Because of the need for dexterity, other impact gloves are much slimmer than the ProGauntlet. These gloves are usually designed to be useful in many different industries. Perhaps these gloves do not offer the same level of impact protection, but they have other features such as a high level of grip on the palm [53].

Other impact gloves also cost much less, at around $25 - $80 per pair. The ProGauntlet is many times more expensive at this moment and does not offer similar benefits besides impact protection. Examples of impact gloves are shown on the right[6].

A conversation with a carpenter made it very clear: people working with hand tools and different materials need to have their fingers as "free" as possible. He said that he usually doesn't even wear thin gloves because of the lack of fingertip feel that is needed to use small items like screws and nails. Even if this means injuring his hands.

[6] http://ae.midas-safety.com/category/hand-protection/armor-extreme-hv-impactpro
https://northseaworkwear.com/pgl126gl-wenaas-odin-extreme-6-6363-cut-5-impact-hand-protection-work-glove.html
https://safety.honeywell.com/en-us/products/by-category/hand-protection/gloves/honeywell-rig-dogtm
https://www.mechanix.com/us-en/durahide-m-pact-framer-impact-framer-gloves

IMPACT PROTECTION STANDARDS

The protection standards for industrial equipment are frequently updated, and since the last update there are three levels of impact protection defined in the ANSI standard of protection, which is used in the United States. In Europe, impact protection is usually merely measured through a pass/fail system [44]. The ProGauntlet will likely easily pass the highest level, ANSI level 3. In fact, just the inner glove would maybe already pass level 1 or 2, since the only property tested is the transmitted force upon impact by a 5.5-pound steel weight that is dropped on the knuckles and fingers only [57].

OTHER PROTECTION STANDARDS

Impact protection is not the only feature of industrial gloves that is tested by international safety standards. The other protection standards against mechanical risks include: Abrasion, Cut, Tear and Puncture resistance [44]

The ProGauntlet is likely to score low in most of these categories, since the shell does not cover the inside of the hand. The ProGauntlet will likely score very high for impact protection, but the glove is not made with the other mechanical risks in mind.

The mentioned risks are just the mechanical risks. Other, non-mechanical risks are also present in many industries. Examples of these are temperature, chemicals and electric conductivity. The ProGauntlet also isn't optimized for these risks.

The aforementioned safety standards aren't static entities. They are updated frequently, so staying compliant with those can be difficult for CrossGuard [44].

Even though the impact protection of the ProGauntlet is without doubt impressive, the glove is currently missing a lot of features that other safety gloves do possess. Mainly the lack of fingertip feel and dexterity make it unlikely for the ProGauntlet to be useful for industrial purposes.

SAFETY COMPLIANCE

As mentioned before, the violation of safety protocols is a major causal factor of occupational injuries. Especially young male workers under the age of 30 typically display the least amount of compliance to safety measures compared to other age and gender groups. This group often prioritizes other goals at the expense of personal safety [55]. However, this group is well represented in many industries, and most occupational hand injuries also occur within his group [58]. Requiring workers to wear the ProGauntlet at industrial workplaces such as oil rigs etc. will only have a positive effect if people actually wear the gloves. This will likely only happen if the ProGauntlet doesn't interfere with the performance and productivity of workers.

USABILITY OF THE PROGAUNTLET IN INDUSTRY

Apart from the injuries that it may or may not prevent, the ProGauntlet does not really fit in the industrial context from a usability perspective either. Dexterity, feel and precision are required in most situations in which people use their hands: construction, manufacturing, on oil rigs, etc..

Usability tests have shown that it can be difficult and often even impossible to pick up small items while wearing the ProGauntlet. The fingertips are thick and are fully covered in a hard shell, which also makes them quite slippery. In its current shape, the ProGauntlet will most definitely interfere with the performance and productivity of workers.

Unlike sports, the activities and hand movements aren't necessarily clearly defined in industrial settings. The ProGauntlet is designed to offer maximum protection in a very specific situation: hard impacts

on the outside of the hand, likely while holding something. In industry, the use of the hands is usually not limited to such a narrow set of movements and positions. If this would ave been the case, the literature would have been a lot more clear about the exact hand positions.

Moreover, impact is not the only danger in most workplaces, and sacrificing feeling and dexterity for the sake of impact protection can potentially even create new dangers.

The ProGauntlet just isn't a logical solution to the hazards. Definitely not in its current form at least.

CONCLUSION

Occupational hand injuries are a serious problem, but the ProGauntlet is unlikely to improve this situation. Put simply, the ProGauntlet isn't designed for industrial use. It isn't designed with handling objects and doing manual work in mind, and more importantly lacks the fingertip precision to do this. Most importantly perhaps, the ProGauntlet also won't protect against some of the most common types and causes of occupational injuries very effectively.

The ProGauntlet is designed to offer maximum impact protection against impacts, but impact protection doesn't appear to be the most important feature for industrial gloves. The impact protection of the ProGauntlet comes at the expense of many other features that are considered standard for industrial gloves.

The technology behind the articulated impact protection of the ProGauntlet could perhaps be useful if it would be translated to a completely different design that incorporates those other essential features of safety gloves. The project brief, however, states that CrossGuard wants a minimum amount of changes to the design of the ProGauntlet, preferably none at all. In its current shape, the ProGauntlet is highly unlikely to be usable in industrial settings.

2.3 Military & law enforcement

2.3.1 Military

Not much literature on hand injuries in the military is available, but it appears that hand injuries aren't among the most common injuries. Similar to the literature on occupational hand injuries, different studies can be difficult to compare due to their context-specific nature. The literature also suggests that the injury profile in peacetime is different from injuries during times of conflict [59].

TRAINING INJURIES

In general, a large proportion of injuries among combat troops and officers appear to happen during training. Injuries to the lower extremities, such as ankle sprains, form the largest portion of musculoskeletal injuries here. The injury profile does appear to vary greatly per country, so it should be mentioned that this study was done among soldiers in Greece [60].

SPORTS

Sports and physical training account for 11% of all injuries in the US army. This makes it the third most common cause of military injuries for men and the fifth most common cause for women. Men accounted for 94% of all sports injuries. Knee and ankle injuries are the most prevalent sports injuries in the US Army by far, followed by hand injuries. Especially during basketball and football, many of these sports injuries occur [61]. This might have to do with the fact that these two sports are highly popular in the US. This article on military sports injuries suggests some interventions and research directions to decrease the number of sports injuries, but protective gloves aren't mentioned among these [61].

MILITARY HAND INJURIES: STATISTICS

92% of all hand injuries are unrelated to combat. Combat troops, manual workers and engineers/mechanics combined account for 83% of all military hand injuries, according to a study based on the observations of a British Military hospital in Iraq [59]. Most hand injuries occur among combat troops, accounting for one-third of all hand injuries in the military. 30% of all hand injuries happened among performing manual work. Military engineers and mechanics account for another 19% of hand injuries [59].

92% of all hand injuries are unrelated to combat.

Less than 1% of all hand injuries is caused by gunshots

This same study claims that 44% of all hand injuries are caused by blunt impact, including falls. Soft tissue injuries are the most common injury type by far (74%), followed by fractures (14%). Less than 1% of all hand injuries is caused by gunshots [59].

Most of the soldiers sustaining hand injuries do not require hospital admission or surgery. Of the soldiers that do require hospital care, the average treatment time is 3 days, before being discharged. For 8% of all hand injuries, specialist medical care was necessary. In over 70% of these cases, the injuries were fractures [59].

Most of the soldiers sustaining hand injuries do not require hospital admission or surgery.

BURN INJURIES

Burn injuries are often overlooked in the military, but these often cause significant harm to soldiers. Wearing fireproof gloves has shown to significantly reduce the number and severity of burn

injuries among soldiers. In comparison: soldiers wearing fireproof gloves are more than eight times less likely to sustain hand burns than those not wearing these [62].

TACTICAL GLOVES

Gloves that are currently used in the military often resemble heavy-duty industrial gloves. Since the features and qualities show a great number similarities, it might be assumed that the needs of the military are similar to the needs in the aforementioned industries. This is confirmed by the notion that the most important purpose of tactical gloves is to protect against injuries from cutting and slashing, without limiting dexterity. To achieve this, tactical gloves usually feature a thick leather palm and Kevlar on the back [63]. All of the tactical gloves that were reviewed featured less protection on the index finger, as this is the "trigger finger" and thus flexibility and feel are key.

There are multiple types of tactical gloves:

- All terrain gloves: these are made to be resistant to water, dirt, oil and other contaminants.
- Sniper gloves: maximum dexterity, but often offer less protection.
- Needlestick gloves: for environments with a high risk of punctures from needles, such as during drug-related operations [63]

Most tactical gloves appear to have a number of defining features that the ProGauntlet is lacking. For example: high dexterity for handling tools and weapons, flame resistance, a low profile and touchscreen compatibility. Even the most rugged tactical gloves seem to have these features, including multiple safety certifications [64].

2.3.2 Law enforcement

Accidents are the most common cause of injuries, rather than assaults

In contrast to the common perception of the dangers during police work, accidents are the most common cause of injuries, rather than assaults [65].

The situation regarding hand protection for law enforcement personnel (police, SWAT, riot police) is highly similar to that in the military and also similar to the industries that have been discussed earlier. In short, impact protection is not the most important feature that is needed in these gloves. The features that the ProGauntlet lacks for the use in the military, are the exact same as for police gloves. Therefore it is unlikely that the ProGauntlet can be useful in this context.

2.3.3 Firefighters

The outer shell of the ProGauntlet has a maximum operating temperature of about 110 degrees Celsius. It will disintegrate or burn when exposed to higher temperatures, producing hazardous fumes.

Although the fire brigade technically isn't law enforcement, it is often said in the same breath as police. Firefighters might benefit from increased impact protection from mechanical hazards during rescue operations, such as falling rubble. According to the supplier of the PU for the outer shell of the ProGauntlet, the material has a maximum operating temperature of about 110 degrees Celsius. PU is a so-called thermosetting polymer, which means that it does not melt, but instead it will disintegrate or burn when exposed to higher temperatures. This produces hazardous fumes. The maximum temperature is too low for use in settings that involve hot environments and fire, and the fumes can endanger the users. Therefore it is not usable in situations that involve such heat.

CONCLUSION

Hand injuries appear to be relatively common in the military according to the literature, but the exact cause of the hand injuries and a precise definition of the context are lacking. A similar situation is true for law enforcement.

Similar to the use of hands in various industries, the hand movements and interactions in the military as well as in law enforcement aren't as clearly defined as during activities like sports.

Although a large proportion of military hand injuries are caused by blunt impact, the potential risks in the military and law enforcement aren't purely mechanical. The ProGauntlet could potentially offer protection against impact-related injuries, but it will not protect against burns.

Although offering great impact resistance, the ProGauntlet lacks a lot of features that are considered standard for tactical gloves. Impact resistance isn't the most important feature of gloves used by the military or in law enforcement, so the absence of other aforementioned features (e.g. dexterity, flame resistance) makes it unlikely for the current design of the ProGauntlet to be useful or successful in the context of military and/or law enforcement.

2.4 Hand injuries in sports

Of all sports injuries, up to 25% are related to the hand and wrist (although numbers vary between studies). The sports participation rate of the population (in the USA) has increased in recent years, which has also led to a rise in the number of injuries [15].

The injury trends for most sports generally seem to be stable. This suggests that there is room for structural improvements in the prevention of hand and wrist injuries during sports [16].

TYPES OF HAND INJURIES

The type and incidence of hand and wrist injuries differs between sports and gender. According to one study on hand and wrist injuries in high school sports in the USA, there are couple of sports with high injury rates. These are football, boys' lacrosse, softball, wrestling, girls' field hockey, boy's ice hockey, and girls' basketball have the highest rates of hand and wrist injuries [16].

As the ProGauntlet mainly protects against impact-related injuries, these form the main area of interest during this research. Impact-related hand and wrist injuries are most commonly seen in contact sports, for instance ice hockey, basketball, football, rugby and lacrosse [11, 15].

Contact sports are one of the main causes of metacarpal and phalangeal fractures. These fractures account for up to 10% of all fractures [15]. Most of these fractures appear to be caused by direct blows or other impacts. Impact from a bat or stick and falling with a closed fist are named as common causes [11, 17]. Finger (phalanx) fractures can be caused by minor accidents, so sometimes fractures aren't even noticed at first [17].

The amount of thumb injuries differs per sport, but these are generally most common in sports where the risk of falling is high. Such sports include soccer, cycling, skiing and gymnastics [17].

INJURY PREVENTION

Preventing hand injuries in sports altogether would of course be great, but the ProGauntlet cannot protect against every type of danger. Therefore, only certain types of sports injuries are relevant during this research. The ProGauntlet specifically protects the outside of the hand against (repeated) impact. When wearing the gloves, the freedom of movement is almost unrestricted, but the sheer size and bulkiness of the glove makes it difficult to handle objects with the fingertips. The sports that are interesting for CrossGuard should have an injury profile that shows a significant amount of overlap with the protective qualities of the ProGauntlet. The ProGauntlet should help to prevent common injuries without being a burden to the athletes.

The dexterity and fingertip sensitivity are greatly limited while wearing the ProGauntlet, so the current design of the glove is not useful for activities that require these qualities.

For this reason, sports like basketball and American football aren't investigated further, despite the relatively high number of hand and finger injuries. In these sports, nobody uses hand protection, let alone a big glove like the ProGauntlet. The glove is too unwieldy and will definitely interfere with the players' performance. Similarly, during soccer none of the players wear hand protection, except for the goal keeper. These gloves are mainly designed to have stiff fingers with a large surface area to block more balls and a durable and grippy palm to grab the ball. The need for protection is quite minimal. These properties don't align with what the ProGauntlet offers. Besides this, it is a highly conservative sport. Innovations such as the Video Assistant Referee took years to implement due to criticism from many stakeholders.

GAMES VS PRACTICE

Injury risk is often measured in terms of injuries per 1000 athlete exposures (AE). One AE is a unit defining one player participating in a single game or practice [66]. Both male and female players sustained more than twice as many injuries during games than during practice [16, 18, 66]. This is interesting, as games only form a small percentage of all AE. Therefore, the relative risk of injury during games is actually much higher. Additionally, injuries sustained during games are often more severe than those sustained during practice. This is likely to be partially due to the higher intensity of playing during games [18].

BAT-OR-STICK SPORTS

The overall incidence of hand and wrist injuries is relatively high in bat-or-stick sports such as field hockey, ice hockey, lacrosse and cricket [18]. During bat-or-stick sports, the players usually hold the bat or stick in their hands for most of the game. This appears to align with the intended use of the ProGauntlet (holding a sword) to at least some extent. Therefore it is interesting to research this category further.

The exact hand injury statistics for these bat-or-stick sports often differ per study, so it is sometimes difficult to compare the results. Despite this discrepancy in results, a couple of sports can be identified as a recurring theme in multiple studies. These sports are: field hockey, ice hockey, lacrosse and cricket. Therefore each of these sports is investigated more in-depth in this literature review.

HIGH RISK BAT-OR-STICK SPORTS

In the aforementioned sports: field hockey, ice hockey, lacrosse and cricket, the ball or puck forms one of the greatest risks. The high velocity of this hard ball or puck forms one of the main injury risks, especially without wearing gloves [18].

During sports like ice hockey and lacrosse, players already wear protection to lower the risk of hand injuries. This is also reflected in the injury statistics. The amount of metacarpal, finger and thumb injuries appears to be significantly higher among ungloved field hockey players, compared to gloved athletes in hockey and lacrosse [11, 19].Especially the number of finger fractures is much higher than in other sports [19]. That said, hand injuries appear to be common in all of these sports.

Hand, wrist and finger injuries among women playing bat or stick sports is estimated to be between 8% and 25% of all injuries sustained [18].

2.4.1 Field hockey

In 2018, about six percent of all sports injuries in the Netherlands were caused by field hockey, putting field hockey in fourth place when it comes to the number of sports injuries [22].

Over 70% of all injuries are due to impact from either the ball or a stick [67].

An interesting contrast with other sports is that more than half of the field hockey injuries in the Netherlands occur among women (55%) [22]. In the other sports that are discussed, men generally account for a higher proportion of injuries.

"Over 70% of all injuries are due to impact from either the ball or a stick"

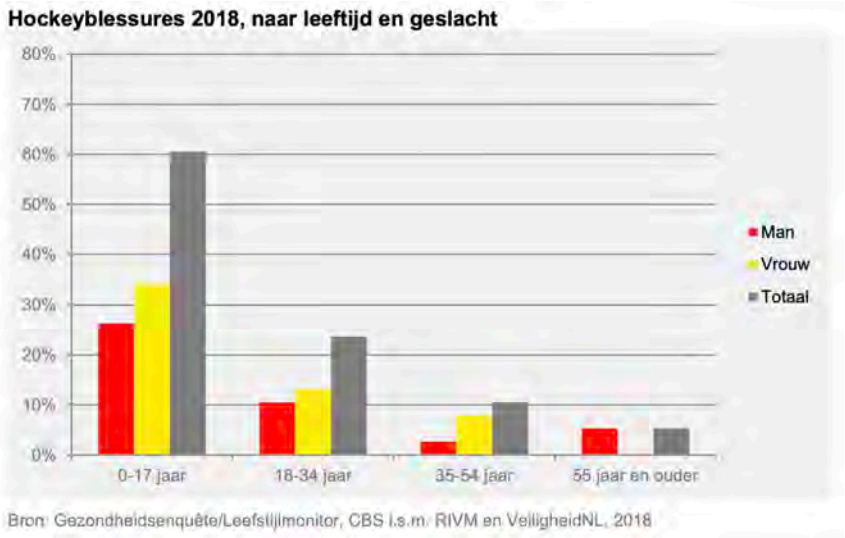
HAND INJURIES

While the numbers vary between studies, hand injuries during field hockey appear to be among the most common types of injury. One study reported that 54% of the field hockey injuries that require emergency treatment are upper extremity injuries [22]. According to others, hand fractures are the second most common injury type after ankle sprains among female field hockey players [19]. Hand injuries account for around 10% to 20% of all injuries [67, 68].

"54% of the field hockey injuries that require emergency treatment are upper extremity injuries"

61% of all hand injuries are caused by ball or stick contact, and the left hand is injured over three times more often than the right hand [68].

Contrary to most other sports, youth players have a higher risk of hand injuries than senior players [68]. This concurs with the general



injury statistics in the Netherlands. According to these statistics, 61 percent of the players injured were under the age of 17, and 24 percent of the injured were between ages 18 and 34 [22]. One study disagrees with this, and claims that the proportion of hand injuries in

US college hockey is higher than in US high school hockey, likely due to the higher velocity of the ball and an overall change in playing style [19].

"Contrary to most other sports, youth players have a higher risk of hand injuries than senior players"

The direct medical cost of a hand or finger fracture is around 1000 euros on average in the Netherlands. Hand and finger fractures are the most expensive injuries in the context of hockey, both in direct costs per injury, as well as the combined costs for the entire hockey industry [22].

GLOVE USE

Even though hand injuries are a known problem in field hockey, the use of protective gloves remains uncommon [68]. In the Netherlands, wearing gloves is only required for indoor hockey [27].

"Even though hand injuries are a known problem in field hockey, the use of protective gloves remains uncommon"

The use of gloves is not compulsory for field hockey players, so players can choose whether they want to wear gloves or not. From an injury prevention perspective, gloves are known to be effective [68]. However, some concerns have been voiced about the possibility that the nature of the game will change due to a change in protection. Some think that protective equipment might put other players at risk [69]. It is therefore important to make sure that the gloves on their own don't become a danger for other players.

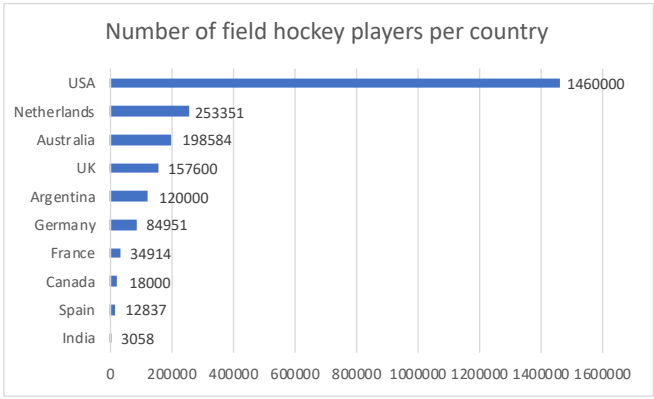
On higher levels of play, the ball can reach speeds over 100 km/h, and therefore glove use is generally more common among high-level players [27].

The fact that not many players wear gloves might make it difficult to introduce the ProGauntlet in the field hockey market, as it would require a behavioral change of the players.

MARKET SIZE

Statistics of the worldwide field hockey market vary, but the worldwide population of field hockey players appears to be around 2.4 million. This is based on statistics about the hockey population in multiple countries, as well as an internal report from CrossGuard and information from insiders in the world of (high-level) field hockey.

The largest uncertainty is the exact number of players in the USA. According to one survey, there are around 1.46 million players [70] almost one million players worldwide. This was confirmed by a former goalkeeper of a national field hockey team.



The number of field hockey players per country. Source: internal report from CrossGuard (2020).

FIELD HOCKEY IN THE USA

About 1.5 million of the 2.4 million hockey players in the world are located in the USA.

HIGH SCHOOL FIELD HOCKEY

Almost 64,000 teens compete in high school field hockey in the USA

COLLEGE FIELD HOCKEY

In the USA, many of the players participate in college field hockey, as over 300 universities have field hockey teams. Those are all women's teams, as college field hockey is not offered for men in the USA. College field hockey is most popular in the northwestern states of the USA, but its popularity is spreading through the rest of the country as well [24].

According to insiders in the field hockey context, the number of college players in the USA is in the hundreds of thousands. According to the same source, the sport is growing fast outside the "traditional" field hockey countries. Russia, Poland and China were named as examples of countries where the sport is growing fast.

INCOME

In the Netherlands, sports participation rates are slightly higher among people with an above-average annual income. In field hockey, this is especially pronounced, as 47% of all players reportedly have a high income [26]. This won't have any effect on the functionality and usability of the ProGauntlet in the context of field hockey, but it does show that hockey players might be able to afford a more expensive glove.

CONCLUSION

Hand injuries are a known problem in field hockey and injuries are most often caused by ball or stick impact. This aligns with the qualities of the ProGauntlet quite well, so it can be worthwhile to investigate the usability of the ProGauntlet in this context through user interviews. The ProGauntlet is a big step away from the current situation regarding hand protection, which might make it more difficult to successfully introduce it in this market. This can also be validated during the interviews.

2.4.2 Ice hockey

The total population of ice hockey players consists of over 1.7 million worldwide. The bulk of these live in Canada (621.000) and the USA (568.000). Other large hockey populations (55.000 - 122.000 players per country) are found in the Czech Republic, Russia, Finland and Sweden respectively. Switzerland, France, Germany, Japan, Slovakia and Norway also have an smaller but active community (10.000 - 28.000 players per country) [71].

Elite players can skate over the ice at speeds close to 50 kilometers an hour and can shoot the puck at speeds over 160 km/h [66].

ICE HOCKEY INJURIES

In the USA alone, up to 20,000 ice hockey players visit the emergency department each year [72]. Collisions, with other players or by crashing into the boards, comprise over 50% of all injuries [66].

Some sources claim that the distribution of injuries among the players is proportionate [73], while others claim that the players in the field are generally injured almost twice as often as goalies [74]. Regardless of the distribution of injuries, ice hockey can be considered a risky sport. 65% of all hockey injuries occur during games, even though games only account for 23% of all athlete exposures. The main reason for this distribution is attributed to the more aggressive playing styles during competition [66]. This is the case for both men and women [73].

Men sustain almost three times as many upper extremity injuries than women during ice hockey. Upper extremity injuries account for around 20% of all injuries, both in competition and practice. Most of these injuries involve the players' shoulder [73].

HAND INJURIES

"Altogether, hand and wrist injuries only account for around 7% of all injuries during ice hockey [75], but when looking only at upper extremity injuries, they make up approximately 35% of the injuries [74]."

The most common hand injury in ice hockey is damage to the thumb ligament due to over-stretching, often by means of stick impact. This is better known as a skier's thumb [72].

Hand fractures account for a third of the total number of fractures. When looking at hand fractures specifically, fractured metacarpals (the back of the hand) are the most common. These make up about two-thirds of all hand fractures. These fractures are most often caused by a direct impact on the hand, usually from a stick [72]. Fights between players (usually with their bare hands) also appear to be a common cause [76], but the ProGauntlet is unlikely to prevent these from happening.

Despite the fact that hand-related injuries do not make up the largest proportion of injuries among ice hockey players, this is nevertheless an interesting market for further research. The ProGauntlet can probably offer better protection against hard blows from sticks, pucks, skate blades, etcetera than the current gloves. In ice hockey, a lot of attention is paid to the equipment, which is reflected by the

level of optimization of many parts of the gear used. However, new innovations tend to be criticized in the beginning [77].

CURRENT GLOVES

The current price of ice hockey gloves ranges from $90 to $180 [78].

Some teams wash their gloves every 2 to 3 days, which is more frequent than most other ice hockey equipment. This is partially to limit bad smells, but it also concerns player health: poor hygiene of heavily used gear can lead to bacterial infections among players [79].

CONCLUSION

Ice hockey could be an interesting market for further research. The total number of players is large and mostly concentrated in a small number of countries. As it is an aggressive, physically intense sport, players are in need of good hand protection. The ProGauntlet might offer better protection than the current gloves do, but the usefulness and practicality of it will need to be assessed through further user research.

2.4.3 Cricket

Although the prevalence of cricket injuries has increased over the past decades, the average severity of those injuries has decreased [80]. Cricket injuries are relatively rare among recreational players, but common among elite players. This is mainly due to the higher intensity of play and the higher workloads [81]. Among these elite players, injuries are most often due to overuse and impact [80]. The 150-gram ball can be bowled (thrown) at the batsmen at speeds up to 160 km/h, often with an unpredictable trajectory, due to the bouncing and spinning of the ball [80].

The "bowlers", the players who throw the ball, get injured more often than other players. Especially the "pace bowlers", who throw the ball as fast as possible, often have injuries related to overuse and excessive stress on their muscles and ligaments. The lower back is one of the most injured regions for these players [81].

The most common cricket-related injury types are sprains, dislocations and fractures. In terms of the location of injuries, the head, hands and wrist are injured most often, respectively, according to one study [82].

HAND INJURIES

The statistics on hand injuries differ between studies. According to one study, hand injuries account for up to 13% of all cricket injuries [80]. Another study claims that, measured over a period of 10 seasons, wrist and hand fractures are the third most common type of injury among cricket players, both male and female [18].

A closer investigation shows however, that most of those injuries aren't caused by impact during batting, as one would expect. Even though some hand and wrist fractures injuries do occur among batsmen, the majority of hand injuries sustained by professional cricket players happen in the outfield during games, and are related to catching the ball rather than hitting it [80, 83, 84]. In these situations, impact-related finger injuries from catching the ball are the most common type of hand injury.

"The majority of hand injuries sustained by professional cricketers occur whilst fielding"

- Despite the fact that most injuries happen during fielding, the current rules of cricket do not allow any other players than the batsmen and wicket-keepers to wear gloves [84].
- The gloves that are worn for batting and wicket-keeping appear to offer enough protection, as not many injuries happen to players in those positions [84].

CONCLUSION

For the ProGauntlet to work for cricket players, the rules would need to be changed, but even then it's unclear whether the ProGauntlet would even offer protection against injuries from catching the ball. Therefore, judging from the literature, it is unlikely that the ProGauntlet can be sold in the cricket market. Batting would be the only activity on the field where the ProGauntlet could add value, this isn't where many injuries occur, as the current batting gloves already seem good enough for the players.

2.4.4 Lacrosse

MARKET SIZE

Lacrosse is mainly popular in the USA and Canada. The largest lacrosse population is concentrated in the USA, which has approximately 2.1 million active lacrosse players [85].

Lacrosse started as a sport with limited physical contact. Women's lacrosse is still a non-contact sport. Men's lacrosse however, has developed into a high-contact game in the last 70 years [86]. Lacrosse is often compared to other stick-based sports like field hockey, but the interaction between players is actually more comparable to contact sports like American football. Body checking and stick checking are allowed and have a significant effect on the playing style and injury profile of lacrosse players. Collisions and impacts from sticks are some of the main causes of Injuries during lacrosse [86]. To limit injuries, the players wear a lot of protective equipment: gloves, helmet, mouth guard, shoulder, elbow and rib protectors and a cup [86].

HAND INJURIES

Among male college-level lacrosse players, hand and wrist injuries account for 7.8% to 11.4% of all injuries [87]. This group also has a higher risk of thumb fractures and other thumb-related injuries than women's lacrosse players and male ice hockey players. More than 50% of the thumb injuries are caused by impact from another player's stick [88].

SEVERITY OF HAND INJURIES

The number of hand injuries during lacrosse seems to be relatively low compared to other types of injuries, but hand and wrist fractures result in the second highest average lost days of play (19.5 days) of all injuries in lacrosse [88].

THUMB INJURIES

Thumb injuries are a problem in men's lacrosse despite the padding in the current gloves, and there have been calls for improvements in thumb protection. The tip and the sides of the thumb are especially exposed, since the protective padding doesn't cover these parts. These parts are therefore highly vulnerable [88].

"there have been calls for improvements in thumb protection"

- The relatively high rate of thumb injuries indicates that there might be a need for better thumb protection [86]. Some gloves feature plastic or carbon thumb inserts [89], but the problem still persists. The thumb protection of the ProGauntlet might therefore be useful in Lacrosse.

GLOVE REQUIREMENTS

The only official requirements for lacrosse gloves appear to be that they need to fully cover the hands and aren't allowed to have holes. Goalkeeper gloves are also required to have extra thumb protection [90]. Thumb injuries are most common among goalkeepers, but in those cases the injuries are usually caused by impact from the ball [86].

- Gloves are said to be the most important piece of equipment in lacrosse, especially the thumb. The glove should ideally give the player a natural feel when holding the stick. It should be

lightweight and flexible to maximize the handling of the stick [89].

The ideal glove should both protect the entire hand, including the tip of the thumb, and should stay slim enough to allow maximum stick control [88]. In current gloves, flexibility is achieved through segmentation on the finger and thumb padding.

"The ideal glove should both protect the entire hand, including the tip of the thumb, and should stay slim enough to allow maximum stick control"

- The main reason that thumb protection is so difficult to improve, is the fact that the freedom of movement and feeling of the thumb are responsible for the quality of stick handling. At the same time however, the thumb is the most exposed to risks [89].

LACROSSE VS. ICE HOCKEY GLOVES

Lacrosse gloves are quite similar to ice hockey gloves, but there are some differences. Lacrosse gloves need to be more flexible around the wrist due to the more numerous ways of holding and "cradling" the stick than during ice hockey. Therefore lacrosse gloves have a softer and less protective cuff. Lacrosse gloves are generally also more lightweight than ice hockey gloves and are constructed from thinner, more breathable materials [91]. It appears that much more flexibility, precision and agility is needed in the hands during lacrosse, compared to ice hockey.

PRICE

Lacrosse gloves cost between $30 - $180 [91].

CONCLUSION

It is unclear if the ProGauntlet as a whole will be useful for lacrosse, but the design of the thumb might potentially be a solution to one of the major problems during men's lacrosse. It should offer superior protection of the entire thumb (including the tip), while maintaining the freedom of movement. The shell of the ProGauntlet is not segmented like the current lacrosse gloves, so there are no weak spots. Lacrosse appears to be interesting enough to justify further user research.

2.5 Motor sports

2.5.1 Motorcycle riding

When seeing the ProGauntlet for the first time, many people think that it's a motorcycle glove. A couple of motorcycle riders expressed their interest in the glove, so therefore it seems worthwhile to research the literature on motorcycle gloves and injuries.

Serious injuries appear to be rare during casual motorcycle riding. For road racing and motocross on the other hand, injury rates can be high [92]. During road racing (MotoGP) the amount of crashes is very high: almost 10 crashes happened for every 100 rider hours. Despite this, the riders are only injured in 9% of all crashes, according to one study [93]

According to one study, motocross has a lower injury rate than motorcycle road racing. The same study shows that the injury rate of motocross is over 5 times greater than that of cycling [94].

In contrast, trial biking was found to be safe. As with most other sports that have been discussed, the literature mostly states that injuries are far more common during competition than during practice [95]. Despite this, there is one study on elite motorcycle racing in Japan, that suggests that injuries occurred significantly more often during practices than during races in both road racing and motocross. The authors suggest that the riders test the limits of their motorcycle during practice, which can result in more accidents. [92].

An interesting finding is that the level of skill and experience don't seem to influence the injury rate among motorcycle riders. It is suggested that novice riders injure themselves due to mistakes more often, whereas advanced riders are more likely to drive faster and take more risks, which results in a similar number of injuries. Therefore, the use of proper safety equipment is important for all levels of riders [92].

CONCLUSION

The literature does not give any answers about hand injuries specifically, or the use of hands during motorcycle riding. Therefore it is necessary to talk with users to find out more about this subject, in order to assess if the ProGauntlet can be useful in this context. It's a common reaction for people to think that the glove is made for motorcycle riding, so this can be a good starting point for interviews about the usability of the glove.

2.5.2 Motocross

Motocross as a sport is growing in popularity. Although recent participation numbers are hard to find, it is known that in 2004 at least 50,000 people participated in competitive off-road motorcycle riding throughout Europe [94]

According to one study, motocross has a high incidence of hand and wrist injuries, compared to most contact and non-contact sports. This same study states that over 90% of all hand and wrist injuries happen during competition-related riding, rather than during recreational riding [95]. One hypothesis on why motocross doesn't show up in many statistics, is that the absolute number of injuries is probably lower than for, say, lacrosse or field hockey. This would be due to a smaller amount of participants in total.

Another study, however, claims that the amount of hand is extremely small, even below 1% [94]. This huge discrepancy in outcomes indicates that these statistics should be interpreted with a high degree of caution. The numbers could either be unreliable due to small sample sizes, or the injury patterns could perhaps be highly dependent on the exact context.

CAUSES OF HAND AND WRIST INJURIES

In terms of hand and wrist injuries, wrist fractures are said to be the most common injury. Metacarpal and phalangeal fractures are the second and third most common, respectively [95]. Wrist fractures are often caused by the rider crashing into a bump or other feature with their front wheel. Contrary to common belief, falls are often the result of a fracture, rather than the cause of them. When the front suspension of the bike can't absorb the impact, the shock can cause wrist fractures. These, in turn, often cause the rider to fall [94].

Metacarpal fractures are usually caused during falls on the thumb or with a closed fist. Another common cause is that riders crash into the marker poles on the side of the track [94].

Currently, motocross gloves are made out of leather or synthetic fibers like Gore-tex and Kevlar with dorsal padding [94]. The ProGauntlet is a lot bulkier than the slim, low-profile gloves that are currently used.

CONCLUSION

The different studies that were reviewed showed a great discrepancy in results regarding hand and wrist injuries related to motocross. Although hand and wrist injuries do undoubtedly occur during motocross, these aren't suggested to be among the most common or severe injuries. It is also unclear whether the ProGauntlet can protect against the wrist fractures that are caused by impact on the handlebars. Even without analyzing the physical usability of the ProGauntlet during motocross, it can be said that it seems unlikely for the glove to add much value here.

Only if the ProGauntlet proves to be useful for on-road motorcycle riding, then motocross can perhaps be reconsidered. For now though, it won't be researched further.

2.5.3 Mountain biking

About 5.6 million people reportedly rode a mountain bike at least once in 2007. It is not known how many of these bikes were actually used off-road [96]. More recent numbers aren't clearly stated in the available literature.

About 85% of all injuries during mountain biking are related to falls or being thrown off the bike. Over 30% of all injuries related to falls are upper extremity injuries, most commonly a fractured collarbone [96].

Despite the fact that male riders sustain more injuries than female riders, female riders are more likely to sustain severe injuries that need hospital care, according to one study [96].

A very limited amount of literature about hand and wrist injuries in mountain biking is available. Judging from the available literature, hand and wrist injuries don't belong to the most important problems during mountain biking. Combined with personal experience with mountain biking, it seems to be unlikely that the ProGauntlet can add value in this context. The bulkiness and the limited dexterity of the fingers makes it more difficult to control the brake levers and shifters. The current design of the ProGauntlet doesn't appear to be useful for mountain biking, and therefore mountain biking is not researched further.

2.6 Preventing hand injuries in sports

The ultimate goal of the ProGauntlet is to prevent certain types of injuries from happening. A logical way to approach the situation might be to look at the causes of injuries and to assess whether the ProGauntlet can effectively protect against these causes. More protection equals less injuries, right?

Even though the logic behind this reasoning is sound, in reality it can be somewhat more complicated to prevent injuries from happening altogether. Paradoxically, more protection does not always lead to less injuries. In some cases it even causes *more* injuries. Injuries are often seen as something purely mechanical, similar to a cog in an engine breaking due to excessive forces. The problem with this interpretation is that it only looks at effects, rather than at the underlying causes that lead to these effects.

One study proposes a model to assess injury risk based on a number of factors: behavior/attitude, training, skills, coaching, equipment, the environment and other competitors. This model suggests that injury risk depends on far more factors than just mechanics. In fact, it suggests that better protection can lead to more risk-taking behavior due to a higher level of confidence [97].

If we take a closer look at this relation between confidence and risk-taking, it appears that injury risk is not only dependent on one's objective physical safety, but also on the subjective feeling of safety. This can be a problem if the feeling of safety greatly exceeds the actual safety. In other words, if the ProGauntlet gives users a feeling of invincibility, then these users might take disproportionate risks, which ultimately results in injuries. These injuries can involve just themselves, but they also might involve other people.

It is difficult to test these effects in practice, as they will differ per person and per situation. These effects should nevertheless be considered when defining the next market for the ProGauntlet. The relative risk of injury of each sport may be a general indication of people's attitudes towards risk taking. One way in which the potential increase in risk-taking behavior could be assessed by incorporating questions about risk-taking in the interviews. This way, it can be determined if their behavior is currently limited by the quality of hand protection, and if they are likely to take more risks if they wear better protection.

2.7 Initial market research: conclusion

The main directions for the research into potential markets for the ProGauntlet have been determined mainly through a combination of a literature study about common causes of hand injuries, information provided by CrossGuard and conversations with potential users. The main directions that followed from this were a number of different sports, industrial applications and military & law enforcement.

For each market the amount, proportion and types of hand injuries were analyzed. Afterwards, the potential role of the ProGauntlet was evaluated for each context. This evaluation focuses mainly on the usability, the benefits and the possible drawbacks of the ProGauntlet in each market. The price is not that important yet, as it first needs to be determined if the ProGauntlet can be useful in a different context at all.
One of the main recurring themes is that extreme impact protection often isn't the only important factor involved in protecting the hands, for the activities that are discussed. The ProGauntlet offers an extremely high degree of impact protection, but at the expense of other qualities, most importantly dexterity. This is a problem in a number of activities. In Appendix 3, an indication of the degree of the product fit for each activity is shown visually.

Hand injuries in sports

ARMED MARTIAL ARTS

- **Kendo:** Perhaps. Due to the use of wooden swords, hand injuries appear to be less common and less severe than in HEMA. On the other hand, kendo is a large market and mainly the advanced players suffer from hand injuries. If the ProGauntlet can offer additional benefits over the current gloves, then kendo might be a viable market.
- **Filipino martial arts:** Likely, but maybe not for everyone. The interviewed players have expressed their interest in the ProGauntlet and the protection it offers appears to align well with the needs during training activities that involve (metal) swords or blades. Filipino martial arts cover a wide range of different armed and unarmed fighting techniques, so the ProGauntlet might be more useful to some FMA practitioners than others, since not everybody uses the same weapons and/or techniques. One of the interviewees has already pre-ordered a ProGauntlet.

BAT AND STICK SPORTS

This category followed from my literature research into causes of hand injuries and it is also a category in which CrossGuard has expressed their interest.

- **Cricket:** No, since most hand injuries occur during fielding. Glove use is forbidden during fielding and the ProGauntlet protects the outside of the hand rather than the inside (which is needed during catches). The current batting (hitting) gloves seem to give enough protection already.
- **Field hockey:** At the moment, no. Maybe a heavily stripped-down version, but this will require a complete redesign. The glove is too big, too heavy, too restrictive and too warm. Less protection would still suffice and the glove should lose its bulkiness.
- **Lacrosse:** perhaps, although there are some drawbacks for the current design, the protection that the ProGauntlet offers appears to be very much aligned with the needs of lacrosse players. The players were especially interested in the thumb protection. Further research is needed, but it looks promising and at least some of the functionality of the ProGauntlet could be translated to the lacrosse market.
- **Ice hockey:** Perhaps. Interviews with ice hockey players are needed to gain more relevant insights, but the qualities of the ProGauntlet seem to align with the needs of ice hockey players. The needs of ice hockey players and the current design of their gloves is similar to lacrosse.

MOTOR/BIKE SPORTS

- **Motorcycle riding:** Perhaps. The wrist protection might need a redesign, but a lot of interviewees (in other markets) thought that the ProGauntlet was made as a motorcycle glove. More interviews with motorcycle riders will be needed to validate the usability, as the thickness of the fingers might interfere with the brake handles. The esthetics of the glove already fit in the motorcycle context quite well.
- **Motocross:** Perhaps, but less likely than on-road motorcycle riding. The glove likely won't protect against injuries caused by impacts from the handlebar, which is a leading cause of hand/wrist injuries. The needs of motocross don't align with the qualities of the ProGauntlet very well.
- **Mountain biking:** No. The protection that the ProGauntlet offers does not align that well with the needs of mountain bike riders. Besides this, the glove is also much bulkier than anything else on the market and it will likely interfere with the ability to control the brakes and shifters.

Occupational hand injuries

No. Most occupational hand injuries are related to tools and machinery, which are mainly found in industrial settings. The industries in which hand injuries are common, are manufacturing, construction and the oil and gas industries. Overall, it appears to be unlikely for the ProGauntlet to be useful in these markets, due to a combination of factors. The main causes and types of injuries do not align with the qualities that the ProGauntlet can offer. The ProGauntlet has plenty of impact protection, but this isn't the most important feature for these industries. The impact protection comes at the expense of many other features that are considered standard for industrial gloves, such as dexterity, fire resistance and certifications for various types of protection. These are all lacking in the ProGauntlet.

Additionally, many industrial hand injuries are caused by violation of safety protocols, so the value of the ProGauntlet is highly debatable. Despite the good impact protection, the glove is still unlikely to protect against the most severe types of injuries, such as crushing and amputation.

The ProGauntlet can only be useful in industrial settings if it is completely redesigned or perhaps in specific niche activities, but further research will be needed to judge this.

Military & law enforcement

Military: No. Despite the fact that the types of hand injuries appear to align with the qualities of the ProGauntlet, the exact cause of the hand injuries and a precise definition of the context are lacking. Many hand-related activities appear to be comparable to industrial work in terms of needs, which is also reflected in the current gloves. The ProGauntlet can't compete with these in terms of features.

Police: No. Highly similar to the military context, the exact use of the hands during police work is unclear and variable. The ProGauntlet also lacks a lot of standard features in this context.

Firefighters: No. The maximum operating temperature of the PU shell of the ProGauntlet is 110 degrees Celsius. Above that, it will disintegrate, which produces hazardous fumes. This is too low for use in settings that involve hot environments and fire.

Appendix 3: Assessment of product fit per market

AFTER LITERATURE RESEARCH

	Type of impact protection	Freedom of movement	Full articulation of fingers	Used to wearing gloves	Clearly defined activity	Inside of hand unexposed	High proportion of hand injuries	Frequent impact	Fingertip feeling less important	Within temperature range	PG allowed by regulations or laws	No design changes
HEMA	x	x	x	x	x	x	x	x	x	x	x	x
Kendo	x	x	x	x	x	x	x	x	x	x	-	x
FMA	x	x	x	x	-	-	x	x	x	x	x	x
Field Hockey	x	x	x	\	x	x	x	-	\	x	\	
Ice Hockey	x	x	x	x	x	x	x	x	\	x	-	\
Lacrosse	x	x	x	x	x	x	x	x	\	x	-	\
Motorcycle riding	x	x	x	\	x	x				x	x	-
Cricket	x	x	x	\	x	x	x	\	\	x		
Industry		x	x	-						x	\	
Police	\	x	x	-						x	\	
Military	\	x	x	-						x	\	
Firefighters	\	x	x	x							\	
Mountain biking	x	x	x	\	x	-				x	x	
Motocross	x	x	x	x	x	-		-		x	x	

AFTER USER RESEARCH

	Type of impact protection	Freedom of movement	Full articulation of fingers	Used to wearing gloves	Clearly defined activity	Inside of hand unexposed	High proportion of hand injuries	Frequent impact	Fingertip feeling less important	Within temperature range	PG allowed by regulations or laws	No design changes
HEMA	x	x	x	x	x	x	x	x	x	x	x	x
Kendo	\	\	x	x	x	x	–	x	x	x		
FMA	x	x	x	x	–	–	x	x	x	x	x	x
Field Hockey	x	x	x	\	x	x	x	–	\	x	\	
Ice Hockey	x	x	x	x	x	x	–	–	\	x	–	\
Lacrosse	x	x	x	x	x	x	x	x	\	x	–	\
Motorcycle riding	x	x	x	\	x	x				x	x	–
Cricket												
Industry												
Police												
Military												
Firefighters												
Mountain biking												
Motocross												

Appendix 4: User research findings

Kendo

No. of participants: 1

Participant 1

Country of residence: Canada

Level/role: 5th Dan, instructor

Age:37

Years of experience: 17

The verdict on entering the kendo market with the ProGauntlet is quite short: No.

During the initial research, kendo appeared to be a possible market because it seemed to resemble the interactions of HEMA, but the user research has shown that kendo is completely different from HEMA in terms of risks, injuries and needs.

TRADITIONAL ENVIRONMENT

Executing techniques perfectly and following traditions seem to be two main pillars of kendo. Using a different type of protection would potentially change both of these.

"Kendo as a sport is quite limited by tradition too. Everything in kendo is very tightly defined in that regard. There are clear rules that tell what you're allowed to do."

To illustrate the level of commitment to traditions, the interviewee said that anything that doesn't look exactly like the current protective gloves (the *kote*), will not be allowed at training sessions and during tournaments.

"What you should keep in mind, is that kendo is quite traditional. A glove can never look different from the standard one.

So if you have extra hand protection, it has to be something that fits in, that you can put on underneath, because you can't just arrive with something

fundamentally different from the standard blue glove. You cannot arrive with a plastic glove."

"This glove won't be useful for kendo, especially because it does not exactly fit under a kote and it cannot replace the kote within the sport as it is now."

Apparently the type of material of the hand and wrist protection is so specific, that the referee uses the sound of impacts to judge whether a strike is good or not. Kendo is a Japanese martial art, so Japan is also the leading country in the kendo world. Deviating from the Japanese traditions and materials appears to be unlikely to be successful.

"When you hit the kote, it makes a certain sound. At tournaments, the referees also listen for that sound. They know what it sounds like when you are hit in a certain way, and based on that they can assess whether it is a proper hit, or whether it slips off, for example. So if you use a different material for that, you will have problems with that."

ACCEPTANCE OF INJURIES

To a great extent, hand injuries just seem to be accepted as a risk of kendo. Not only that, these injuries are often even seen as an important part of the learning curve. The mental challenges of taking risks and reading your opponent, are important elements of kendo, and injuries are inherently a part of these mental challenges.

"Anyway, it's a martial art of course, a few bruises and sore spots are just part of the deal, you know?"

"There are also certain wrist guards, which are extra thick on the side of your wrist. Those are things that might improve your quality of life, because then you no longer such a thick purple bruise on your hand, but then nobody learns to hit well anymore."

People that wear additional protection are frowned upon by some, as this would influence their technique in a bad way, thus changing the sport. This perception might vary between different practitioners and at different skill levels, but it can nevertheless be said that the hard shell of the ProGauntlet is "overkill" for the dangers of kendo. In general, hand injuries aren't the biggest problem in kendo.

"If you have so much protection that you don't feel it when you get hit, is it then still really kendo, you know? You should be able to feel some impact."

The swords that are used have completely rounded edges and are made out of bamboo. They bear more resemblance to wooden sticks than to the heavy, metal HEMA swords.

"I think I have seen a broken hand only once. Usually they just get bruised."

"Some of the people of our club wear extra protection on their hand."

Due to the use of much lighter weapons, serious hand injuries do not appear to be common in kendo. Bruises are more common, and the people who want to avoid these often already wear some additional padding underneath the traditional gloves.

"In college I once spoke to someone who was going to study surgery and they were like, "Yeah, I just can't do kendo, because if I hurt my hand, it will prevent me from exercising the fine motor skills that I need for my job. That would simply mean the end of my career"."

As the right hand is always in front of the left hand when holding the sword, this protection is only really relevant to the right hand.

In terms of protection, the wrist protection is too small. During kendo, the wrist is one of the four legal strike zones, so therefore the wrist protection is actually more critical than the protection around the fingers.

DIFFERENT ERGONOMICS

Apart from breaking with the traditions of kendo, the ProGauntlet doesn't offer the protection and ergonomics that are needed during kendo.

"So there's like a 45 degree angle between the wrist and the hand. When you are holding the shinai, you actually have your hand at an angle, compared to your wrist. The shinai lies diagonally in your hand, pointed forward.

In the past I have bought a kote that didn't have that angle, and that took quite a lot of time and effort before it was bent in. It was very difficult to move my wrists in it."

In terms of ergonomics, the wrist and hand should be connected at an angle of about 45 degrees, and the only really relevant hand movement that the user needs to make is a rotation of the hand, sideways, like when striking a nail with a hammer.

CONCLUSION

The only real problem that the ProGauntlet (or a redesigned glove) might solve for kendo, is getting bruised fingers and knuckles. This however, is seen as a part of the sport. It appears to be highly unlikely that the ProGauntlet would be accepted in any shape or form, as innovations aren't met with optimism in kendo.

Besides the interview with a high-level instructor, a national kendo association also confirmed that the ProGauntlet would not be useful for kendo.

Field Hockey

MANY HAND INJURIES

The prevalence of (serious) hand injuries appears to be very high in field hockey. This is found in the literature, and it is also confirmed by the players that were interviewed. All players that were interviewed in this study, as well as the players that were interviewed in an informal manner, all of them had either experienced hand injuries themselves or had knowledge about serious cases in their direct environment.

Scraping the knuckles appears to happen to everyone, every match, and bruised fingers, thumbs and knuckles also seem to be quite common. Serious injuries include fractured fingers and even (almost) amputating fingers.

"When defending, your left knuckles are usually facing outwards, so that's where you get hit most often. And on the right hand your thumb gets hit the most, by far."

"My knuckles always get messed up, especially the middle knuckles, those in the middle of your fingers."

"If you put your hand on the ground, the skin on your knuckles will rip open with even the slightest movement."

IMPACT INJURIES

Most, if not all, (serious) hand injuries appear to occur through an impact from either the ball or another stick. This aligns well with the protective qualities of the ProGauntlet.

"Most of my hand injuries were caused by another stick. Or a ball. But actually both happens quite often."

"If you are a defender, you often stand in the line of fire when a ball is shot at the goal. It can hit your hand, and that hurts."

"I think that getting hit on your hand by the ball is the biggest risk during hockey in terms of hand injuries. That happens sometimes and that's quite painful. Or you can get hit on your hand by a stick, but that doesn't happen

very often. I think getting a ball on your hand is the most common. That is the most dangerous."

"It has happened very often, that the ball has hit my thumb. Now I don't even feel my thumbs anymore when it's cold outside, so I'm guessing those have been bruised in the past."

TRAUMATIC HAND INJURIES

Luckily, most injuries appear to be limited to bruises. These usually don't have a lasting effect, but sometimes they do.

Traumatic injuries, on the other hand, do also happen relatively often unfortunately. Multiple instances of broken fingers were mentioned,

and two of the participants knew at least one (different) person who had almost lost part of a finger due to an impact from another stick.

"Last year, there was a girl on my team who almost lost half of her finger. I don't know how it happened exactly, but I think her finger got crushed between two sticks. She's missing a part of her fingertip now"

"I've never broken anything myself, but I do know people who have had broken fingers. One guy even almost lost his finger. An opponent was aiming for the ball, but missed, so his finger got slammed between two sticks. Then his index finger was only hanging on his tendon from the middle phalanx. But that is very rare, I have only seen that once."

NEEDING BETTER PROTECTION

One of the most obvious problems with the current (short-fingered) hockey gloves is that they don't fulfill their basic function: preventing hand injuries. Players mentioned that they had experience with or knew about injuries that happened even while wearing a glove.

Even while wearing a glove, people still sustain hand injuries during field hockey. Besides the physical toll that this takes, this also leads to a change in behavior among many players.

"To me it feels like I'm protecting my hand when I wear a glove, but if a ball were to actually hit it, then this material probably isn't strong enough."

"Sometimes you pull your stick up and let a ball through, because you know that your gloves aren't strong enough. Then you think: no, I am not going to let this ball hit me."

INCOMPETENCE OF OTHERS

Some players expressed that they're not really afraid of getting hit by a stick if their teammates and opponents are competent hockey players. They know how their stick moves and how to time it when they do lash out to hit the ball. This would suggest that the risk of getting hit by a stick is greater at lower levels of play, where people have less control and a lesser understanding of the dynamics of the game.

"When someone who lashes out and hits your hand with their stick, that's just pure incompetence."

The research indicates that the risks of hand injuries differ between elite and amateur players, as does the choice for wearing a glove. At higher levels of play, the intensity is higher, but the precision of every action on the field is also greater. High level players play harder, but they know what they're doing, whereas novice players are less adept in predicting situations and acting accordingly. This can lead to mistakes and possibly injuries.

- Elite players: harder contact, more intense playing, but with more precision
- Novice players: unpredictable, prone to making mistakes, but usually a lower playing intensity

Barriers to wearing gloves

Despite the relatively high prevalence of hand injuries in field hockey, people often don't wear protection because it's uncomfortable, bulky, smelly and just because they don't really see the necessity of it.

This aligns with the findings from earlier conversations with five field hockey players. These players expressed that they were impressed by the ProGauntlet, but that they wouldn't wear it while playing hockey for the same reasons.

SWEATY

"I don't wear gloves during hockey. It's sweaty."

All of the players thought that the ProGauntlet would also be too warm to use while playing hockey. The auto-ethnographic research confirmed that the gloves are quite warm to wear, when in very active settings. Especially with when it's hot outside, the hands can get very sweaty quickly in the gloves.

TOO BULKY

After trying on the ProGauntlet, most players said that they would appreciate extra hand protection, but that the ProGauntlet is too bulky and heavy. They thought that it would affect their performance negatively and were therefore willing to take the risk of wearing less protection or even no protection at all.

"In terms of hand injuries, I've broken a thumb once, while defending. The opponent's stick hit my thumb, then it broke. But I still don't wear a glove. It makes my hand too thick, it sticks out too much."

UNCOMFORTABLE

"I had a glove once that had a Velcro strap. That constantly scraped against my other hand and even made wounds."

(NOT) CHANGING BEHAVIOR

"With better gloves I wouldn't take more risks in duels and the like, because the your head is still more important than your hands, and we're not wearing helmets."

Choosing to wear gloves

LEVEL OF PLAY

The choice on whether or not to wear a glove can be influenced by many different factors, but one factor appears to be consistent: the level of the players. It seems that more advanced players, who play at a higher level, wear a glove more often than those competing on a lower level.

The reason behind this is not completely clear, but it might have to do with the intensity and speed of the game, an increased awareness of the risks or the importance of the hands in high-level competitions

"There are 16 girls on my team. I think ten of them wear a glove."

(high-level midfielder)

"I don't wear a glove myself, and there aren't a lot of people on my team who do. About 2 out of 11 wear a glove on my team."

(midfielder, playing in a recreational team with his friends)

"If you look at those pros, they all wear gloves, or most of them anyway."

EXPERIENCE WITH INJURIES

Sadly, many people only consider to wear gloves after having sustained an injury.

"Most of the people I know don't wear gloves until they've had a hard blow on their hands."

INFLUENCED BY OTHERS

One other player, an attacker, said that he did wear a very slim glove on his left hand. He started wearing this after his former coach made it mandatory for the entire team to wear gloves. After switching teams, he continued wearing the same protection, since he was afraid of hurting his hand if he would take it off. He described this as a feeling of "bad karma". He did point out that the glove affected his performance slightly and that he would like to be able to play without protection. He would not consider wearing bulkier protection, even if it protects better.

"Some guys have been wearing a glove since their childhood. Their parents said that they should wear one, and then they continued wearing it."

"I started wearing a glove for my own safety and because my coach advised it"

DIFFERENT TYPES OF GLOVES

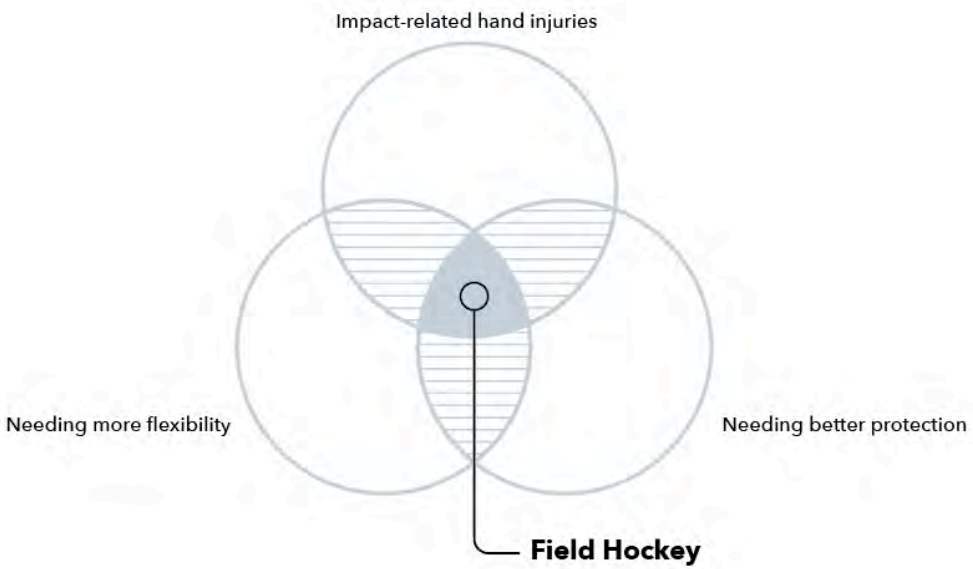
"About three-quarters of the girls [on my team] are wearing gloves, but there are a few different types of gloves."

The current gloves are around €25 per glove, so at €450 per pair, the ProGauntlet would be 9 times as expensive for a single glove.

INDOOR VS OUTDOOR

Field hockey is most often played outside, on a surface of artificial grass, but (mainly during the off-season) it can also be played on an indoor pitch. An indoor hockey pitch is much smaller than an outdoor field, and is usually the same size as a basketball pitch. Because of the smaller playing field, players stand much closer to each other, and therefore it is generally more likely to get hit by a ball or another stick.

The basic rules of indoor hockey are mostly similar to field hockey, but there are a couple of important differences. Most importantly, the ball may not leave the ground unless it is shot directly at the goal. Because of this, the hands and the stick are held much closer to the ground by players.



The combination of a smaller field and being closer to the ground makes the risk of hand injuries during indoor hockey much greater than during outdoor hockey.

"I think indoor hockey has a much higher risk than field hockey in terms of injuries."

"I think that the chance of hand injuries during indoor hockey is like ten times greater than out on the field."

"During indoor hockey, I'm willing to trade some of the freedom of movement for better protection, because I know how important. good hand protection can be."

Other sources also confirm that the chance of hand injuries is greater during indoor hockey:

"A lot of indoor players tackle flat and down low, this means a lot of opportunities for not only abrasions from the floor, but fingers being squashed by the oppositions sticks too." (http://www.best-fieldhockeysticks.com/field-hockey-gloves/)

SPECIFIC USE CASES

Two players said that they thought that the gloves could be useful for penalty corners, as this isa clearly defined scenario when the chance of a hard impact is high. If the players would only wear the ProGauntlet during penalty corners, the warmth of the glove is also less relevant.

WILLING TO CONSIDER A GLOVE

"Maneuverability is actually the most important factor for a glove. After that comes grip, then weight and size. If it also protects well, then that's nice. If a glove has all those features, then it's really just stupid not to wear one."

NEEDS A REDESIGN

"I really like the glove, but I wouldn't buy it in its current form. I think it's too warm for me."

"I think that it's a bit too coarse in terms of freedom of movement and too bulky to move really nicely. And also too heavy."

One female player said that the glove was way too big, which made it useless in her case.

The hockey players weren't sure if the hard outer shell would be allowed on the field, as it could potentially harm other players.

CONCLUSION

The ProGauntlet in its current form is not useful for field hockey, for various reasons. The *type* of protection however, may be very valuable for hockey players. This, in combination with the high number of hand injuries and the amount of room for improvement there is, makes it interesting to explore the opportunities in this field.

According to the original project brief, the answer for field hockey would be a loud and clear "no", when it comes to introducing the ProGauntlet in this market. When thinking about the product in a broader sense however, field hockey does seem to align with the qualities that CrossGuard can provide in a glove.

There appears to be a dissatisfaction with the current design and quality of field hockey gloves. Hockey players need a stronger, more flexible, lightweight impact glove. This sounds like something that CrossGuard can make.

Lacrosse

No. of participants: 3

Participant 1

Country of residence: the Netherlands

Level/role: midfielder

Age: 21

Years of experience: 11

Participant 2

Country of residence: the Netherlands

Level/role: defender

Age: 25

Years of experience: 14

Participant 3

Country of residence: the Netherlands

Level/role: midfielder

Age: 25

Years of experience: 8

In terms of hand protection, lacrosse gloves are quite similar to ice hockey gloves, but the hand movements are much more complex and varied. For this reason they wear slimmer gloves than ice hockey players, despite being prone to a greater number of hand injuries. The stick is manipulated much more precisely than in most other sports.

During lacrosse, players make a lot of different hand, wrist and finger movements. Throwing and catching a ball overhead, scooping it up from the ground, spinning the stick around its axis to secure a catch, quick dodges, redirects and slashes; these are just a few examples of the many different actions a player can take during a game. The wide variety of highly precise hand movements makes it incredibly

important to have as much dexterity, grip and freedom of movement as possible. Fingertip sensitivity is also essential. The gloves are described as the second most important piece of equipment in lacrosse.

"A lot of people will give, for the mobility and feel of gloves, they'll give up protection."

"stick, gloves, cleats are the top three."

A usability test of holding and using a lacrosse stick with the ProGauntlet, shows that it is too restrictive in terms of finger and wrist movements and there are also a number of pinching points, mainly between the thumb and the index finger.

ACCEPTING INJURIES

People would take lighter gloves and wrist mobility over something that's like completely protective. Sure, then they'll never get like their fingers injured, but they would rather be able to score more goals and have faster shots. They'll be like "I'll take the pain" and all that stuff."

I've had a lot of like sprained thumbs. Those usually haven't like taken me out, it just hurts. I just play with the other hand instead.

Especially thumb injuries are a big problem in lacrosse, so the ProGauntlet might be able to offer a better solution here. In terms of market, the problems are very similar to the ice hockey market, with a couple of major brands and big, leading competitions in the USA and Canada.

"Like the thumb can really be like, bent backwards. So it's like really the thumbs that are the problem."

"One of my big issues is the thumb on my gloves. The thumb is just like twice the size which like allows your thumb to like move out and it kind of gets exposed. I wish it was kind of like form fitting and then had like a little more protection like on the inside."

"My thumb would always hyperextend."

Some aspects of the ProGauntlet would be very useful in lacrosse, especially the thumb protection. Risk-taking behavior appears to be a big element in this sport, and the behavior may be partially dependent on the level of protection. Possible challenges for the ProGauntlet might be its weight and the level of stick control. These factors may be more important than protection for many.

One interesting quote was actually about the attitude of (high-level) lacrosse and ice hockey players in relation to their protection. The participant had played lacrosse on a high level in college, but had quit due to injuries.

"I don't know if you know any lacrosse or hockey players, but those guys have a few screws, like, loose in their head. They're just like kind of psycho so I would say they wouldn't change their playing style, they're gonna go and play as hard as they can every time"

TOO MANY INJURIES

"Now I'm retired. I just got a bit tired of getting hit all the time. I was like, I'm gonna get my thumbs broken and skinned, whacked, hit, all that stuff"

"they'll hit up so you'll get like your pinky hit a lot, like defenders will hit up, but the big one is like defenders will hit down and they usually hit down on the back of your hand or your thumb. Those are the two big ones"

"when the defender comes like over the top, they crush your left thumb"

CONCLUSION

Injury acceptance and risk taking seem to be a big part of lacrosse, and players don't want to sacrifice performance. A great number of complex hand movements are used during lacrosse, and therefore the weight and freedom of movement of gloves are extremely important. Even more than in the other sports that were researched. Making a good lacrosse glove proves to be extremely difficult, so it would make sense to design this glove only after CrossGuard has learned from other markets.

Ice Hockey

No. of participants: 2

Participant 1

Country of residence: USA

Level/role: senior hockey player, coach

Age:50-60

Years of experience: 45

Participant 2

Country of residence: the Netherlands

Level/role: center player, first division

Age:21

Years of experience: 17

In general, the interviewed ice hockey players were quite positive about the ProGauntlet. They said it looked like something that they could potentially use, with a few design changes. One main recurring theme was risk-taking behavior, though. Apparently the introduction of face masks has led to more high sticks and less regard for other players' safety. Some coaches even teach players to his opponents exactly between the protection. It would therefore be important to test if the ProGauntlet doesn't make people play much more dangerous, as this would defeat the purpose of better protection.

Flexibility and stick feel are extremely important for ice hockey gloves. Players often rank protection as less important than these factors.

ENOUGH PROTECTION

According to the interviewees, the current ice hockey gloves appear to protect well enough against hard impacts from sticks, pucks, etcetera. Most hand injuries appear to happen by falling, crashing into the boards around the rink, and collisions with other players. This confirms the findings from the literature study on ice hockey injuries.

"I've always had plenty of padding on the backside. I've never had a major sprain because the padding has been sufficient and gloves that I've worn."

According to ice hockey players, the hand protection on the back of the hand is more than adequate: they even use it to protect against other injuries.

"what you sometimes do, is that when the puck flies towards you, you just put your hand in front of your mouth. The outside of your glove, which is completely protected. So not that much can actually happen."

"if I'm buying from a reputable, you know, one of the major brands, their designs are fairly similar.You're gonna have good protection on the back of your palm. And then you know, a little bit off the wrist, you'll have a thick, a little thicker pad, but you're really looking for how it feels and how you move in it."

"Of course there are gloves of higher quality and ones of lower quality, but in general the difference in quality of gloves is pretty small. More expensive gloves don't, like, protect better than cheaper ones"

NOT MANY INJURIES

As current ice hockey gloves appear to offer enough protection, the incidence of hand injuries appears to be low. This is also confirmed by the literature research into hand injuries, where it is found that only about 7% of all injuries involve the hands.

"I've played for 45 years. I've only seen [a really serious hand injury] once."

Gloves have a leading role in these low injury rates, and even though hand injuries still do occur, it is unclear whether the ProGauntlet would effectively protect against these injuries.

"Of course there are guys who've had a hand injury once. But that's usually because they crash into other players or because they fall in an unlucky way, and not really because they get hit by the puck or another stick."

The protection itself doesn't appear to be the problem here, it's rather the gaps in the protection that are the problem.

"There are few other sports, I think, where all your body parts are as protected as in ice hockey. But sometimes a puck or a stick will still end up somewhere where you're not protected and then you get injured there."

RISK COMPENSATION

Ice hockey involves a lot of physical contact, and can be considered a relatively risky sport, according to injury statistics. Despite this, players don't perceive it as much more risky than other sports. This is illustrated by the following two quotes:

"It's a contact sport. You often see that the guys who don't dare to take risks perform less well than those who do."

"Even though people may be taking more risks, there aren't more injuries in ice hockey than in other sports, such as soccer and field hockey."

DANGERS OF PROTECTION

Paradoxically, the protective equipment may reduce certain risks, but it might also increase other risks or introduce new risks.

"Ironically, when face masks were added to the game, there's a theory that high sticks became much more common. Because when people didn't have masks, the theory is that we were all responsible for people's well being. Now that we have masks on, well, if my stick goes up, I'm just gonna hit somebody in the cage, right? So I wonder if people would slash harder on people's hands knowing that they're protected."

Playing harder because of protection appears to be a realistic effect of the equipment that is used during ice hockey. Even though better protection might prevent some injuries, there is some evidence that some people will exploit the weaknesses of any type of protection nevertheless.

"I mean, you're, there are coaches who teach you to check people in spots where there's gaps between pads."

If this is really the case, then it can be doubted if the ProGauntlet would have a positive impact on the safety of ice hockey players.

ACCEPTANCE OF INJURIES

Whether or not the risk-taking behavior is influenced by the protective gear, the players seem to accept some pain and minor injuries as a part of the game.

"I mean, you're gonna play and you're gonna get slashed, you're gonna have a bruise, you know, but I've never had a break."

FLEXIBILITY OVER PROTECTION

As the protection of current ice hockey gloves doesn't seem to be a major issue, players often value other qualities over protection.

"Comfort, fit, flexibility. I probably should have protection in there, too. Shouldn't I? [laughs]"

Choosing flexibility over protection has also had an effect on the physical design of ice hockey gloves over the years. The gloves have gotten shorter to improve flexibility, at the expense of protection.

"Through the years gloves have actually gotten shorter. When I was a kid gloves probably went down. The elbow pad used to basically go almost to where the glove ended up so that you wouldn't have any exposed area but over time, to get more wrist flexibility, the gloves have gotten shorter."

I mean, if you can't, you know, pivot your wrist, you're going to have less ability to maneuver your stick.

I need the ability. So I would be what's considered a skill player. If my gloves inhibit my ability to handle the puck, to pass the puck to shoot the puck, then it would have a major impact on how I play.

DOMINANT BRANDS

Getting into the ice hockey market can be difficult, as the market is dominated by a few major brands. These brands produce highly optimized equipment and have sponsorship deals with many teams. This could be a serious barrier for CrossGuard to enter the ice hockey market on its own, and partnering with existing brands may be necessary.

"I guess I would buy any brand of glove, but typically the market is dominated by a few major brands. It's not like there's 10 companies making gloves out there on a regular basis."

"The top of the line glove is much more expensive than all of the others. Like, 300 euros compared to 100, 150 euros"

WOULD CONSIDER NEW BRAND

"I mean, half of what I own is Bauer. If it was a new brand I would have to understand what it is and understand why it's better. I'd have to learn a little bit more about that brand."

LEADING COUNTRIES

Ice hockey is a very small sport in the Netherlands, and players here look up to the competition in countries like the USA and Canada. It would therefore be essential to aim for these markets if CrossGuard would want to sell an ice hockey glove.

A selling point for ice hockey could be that people could perhaps buy the inner glove separately, as people usually only wear down the inside of the glove. This way, the initial investment is high, but people can replace their inner gloves cheaper. An additional benefit would be that people stay in the "ecosystem" as long as they have the outer shell.

CONCLUSION

Even though ice hockey players appear to be quite positive about the ProGauntlet, its real-life value for ice hockey is not very clear. Unlike in field hockey, ice hockey players don't necessarily need better protection. Players often choose flexibility over protection, so if a glove like the ProGauntlet could improve this significantly, then it might be an option for performance-oriented players. In its current shape however, the ProGauntlet is not really useful for ice hockey. A redesign might improve its chance of success, but there actually isn't a clear problem with the current gloves that needs to be solved.

Motorcycle riding

Next market for the ProGauntlet?

NO

No. of participants: 1

Participant 1

Country of residence: the Netherlands

Level/role: recreational motorcycle rider

Age:26

Years of experience: 4

The case for entering the market of motorcycle riding does not appear to be particularly strong, at least not for now. When looking at the strengths of the ProGauntlet (or a redesigned impact glove with a PU shell for that matter), these don't really stand out in terms of features for motorcycle gloves. For motorcycle riders, protection and feeling are both named as the most important aspect. Good gloves are expected to have both. The level of protection doesn't appear to influence the riding style very much, but the fingertip feeling and dexterity do.

"Being able to really feel your fingers is very important. You use your fingers for everything."

"The feeling in your fingertips is important, you have to know what you're doing with your fingers."

The ProGauntlet is lacking the fingertip feeling that is needed to control the vehicle. Losing control of the motorcycle is named as the greatest risk, and this is directly impacted by the feeling that the gloves provide.

"Protection is the most important feature for me, but having no flexibility in your glove is dangerous, because then you can't control your bike as well."

Even though better protection would be a welcome addition to the existing gloves, there isn't a clear need for better protection for motorcycle riding.

"[The ProGauntlet] actually has a bit too much protection in places where you don't necessarily need it."

The qualities of the ProGauntlet appear to be "nice to have" instead of clear needs. Unlike in HEMA, where the hands are being hit constantly, most motorcycle riders will never hit their hands under normal circumstances.

"I never specifically think about a hand injury while riding a motorcycle. Only if I would crash, but then I'm more afraid that I will break my entire body [laughs]. But I never really think about falling."

"If I fall, I use my hands to absorb the impact. Once I just slipped and fell over in a parking lot when it was very slippery. I fell sideways, so I took the blow with the side of my hand.

The purpose of the protection is to protect the hands is the rare event that the rider would fall or crash. Riders of "naked" bikes (without a windshield), have the additional risk of getting hit on the knuckles by debris and pebbles, but this does not appear to be a disproportionate risk. In serious crashes, the hands don't appear to be the main concern of riders.

One problem with current gloves is temperature control. The glove is often either too warm or not warm enough. As the ProGauntlet consists of a combination of an outer shell and an inner glove, having an interchangeable inner glove could be a selling point for a ProGauntlet-like glove. This way, users only need one protective shell, and can swap different inner gloves throughout the year and throughout the lifespan of the shell.

The esthetics of the ProGauntlet do seem to fit in the motorcycle context quite well. A common response of people when seeing the glove for the first time is: "Wow, is that some kind of motorcycle glove or something?" The interviewee also confirmed that the glove would fit in with the rest of his motorcycle equipment.

"In terms of looks it would certainly fit in with other motorcycle equipment."

The price range of motorcycle gloves appears to be much lower than the current price of the ProGauntlet. What also makes the motorcycle riding different from the other activities that were analyzed, is that it is mostly an individual activity. There are no opponents, and riders don't directly interact with others physically. This can have both advantages and disadvantages for a potential redesign. One disadvantage is that the individual nature of the activity can make it very open to personal preference. This means that it can be difficult to judge if an innovation will be appreciated and accepted in the general market, since priorities can differ greatly between riders.

CONCLUSION

The ProGauntlet would likely protect against most risks, but its real strength, repeated impact resistance, doesn't really align with the needs of motorcycle riders. The feeling of the glove needs to be much better for riders to consider it.

"The protection [of the ProGauntlet] looks very good, and the flexibility too, but I still miss the dexterity."

The use case just isn't as strong as in some of the other activities that have been defined. If CrossGuard would design a lighter glove (for e.g. field hockey), this design could perhaps be translated into a motorcycle glove, but it doesn't seem to make a whole lot of sense to

invest a lot in designing a motorcycle glove at this moment. Even though only one rider was interviewed during this study, other riders also confirmed that dexterity and fingertip feeling are essential qualities of a motorcycle glove. These qualities are currently lacking in the ProGauntlet, and this is definitely a dealbreaker.

Perhaps a complete redesign of the glove would solve this, but even then it is unclear if the protection and structure of the glove can really make it stand out from all the other available gloves.

Filipino Martial Arts / Kali / Escrima / Arnis:

No. of participants: 2

Participant 1

Country of residence: USA

Level/role: Tuhon (top level instructor)

Age: 40-50

Years of experience: 25

Participant 2

Country of residence: USA

Level/role:Instructor

Age:40-50

Years of experience: unknown

DIFFERENTIATING FROM THE MAINSTREAM

As stated earlier, FMA is also known as kali, escrima and arnis. This wide variation of names is telling for the huge number of different interpretations that people have adopted. These different interpretations are known as "systems", which each have their own set of techniques. The FMA practitioners that were interviewed are part of the "Atienza kali" system. They are supposedly "on the forefront of the realism" when it comes to training. With this they appear to mean that they use heavier weapons with metal blades, that can cause significantly more damage to the body than the wooden sticks that many others use.

"We definitely deal more in a realistic type of training. So to get to that realistic type of training and to be safe, you need protection."

"I would like to think that we're, you know, we're at the forefront of the realism portion of the training."

"We don't emphasize a lot of our curriculum on stick fighting, like a lot of FMA. We use aluminum training blades, which mimic swords or machetes blades."

In addition to the choice of weapons, the people from Atienza Kali also differentiate themselves from the mainstream through harder physical contact than other systems.

"Those other systems are more drill-focused. Therefore they don't need all this protection all the time, because they're not really hitting each other. We [in Atienza Kali] try to hit each other. Yeah, that's really the difference. That's why we need protection."

EXPERIENCE WITH INJURIES

The participants expressed a much greater familiarity with hand injuries than in any other activity that was researched. In this type of FMA, both the prevalence and the severity of hand injuries seem to be high. The following quotes illustrate this.

"The hands are targeted primarily so the hands get hit in almost every exchange in training and competition. We have had injuries such as broken bones and blunt force trauma."

"Personally, I have had my two front knuckles and the metacarpals on my right hand, just like incapacitated with being broken."

NEEDING PROTECTION

The FMA practitioners that were interviewed clearly expressed their need for better hand protection. Due to the use of metal blades, they wear down their hand protection very quickly. The current gloves that are used here are often the SPES lobster heavy gloves, and these are not protective enough and don't give enough freedom of movement. One of the interviewees even said that those gloves would already start breaking down after about three weeks of training.

"Our training blades are blunt, but you know, you hit somebody with an aluminum trainer that's shaped like a sword, it's gonna dust bone. It'll destroy bone."

"When we're sparring or when we're doing what we call 'the test', we try to get as much armor so that you know people are not flinching."

HAVING TO RECOVER FROM INJURIES

The consequences of getting injured are very real: recovering from e.g. a broken hand means that they aren't able to train for six weeks. They want to avoid this as much as possible.

"Our focus is to try to make sure that we can try to practice as realistically as possible and and you know not have to sit out for six weeks."

"If you get hurt you're not training again for a couple of weeks. Yeah, so most of the time, you'll be wearing armor of some sort."

"Sometimes it hurts. The armor in like lots of gloves isn't 100% isn't perfect. We've been hit where the armor hasn't been. Some people hit you right in the thumb, where there's no armor"

NEEDING DEXTERITY AND FLEXIBILITY

"the more we can do with our hand the more we can do with the system."

"currently like with the lobster glove like it's nice because as that protection around around the hand but what it doesn't have is the ability for us to like grab stuff as as with as much dexterity"

"I think the protection is the most important part first, but then mobility does help because and it's very close to the second right. […] If I'm sparring then I definitely need mobility, because I need to I need to move that weapon in a certain way. You can also develop more power if you can have mobility."

ACCEPTING INJURIES

"On the highest level, we don't use the armor because we want to see how close we could possibly get [to a realistic scenario]. Again, there's the blades aren't sharp. So, so if anything you would just get a broken hand. But not many people do that level, it's only very few, at the very top level."

AWARENESS OF HEMA

"I mean, we follow HEMA closely, you know, because it does sort of mirror what we do in terms of weapons"

APPRECIATING THE PROGAUNTLET

"And when I personally saw the ProGauntlet, I was like, that is a game changer for us."

One of the interviewees had already pre-ordered the ProGauntlet and another interviewee said that he was ready to buy and test it as well.

"we're ready to pull the trigger just to see how it goes."

CONCLUSION

The interviews suggest that there is a clear need for better hand protection in this particular system of FMA, and the ProGauntlet

appears to provide exactly what these people need. The people that were interviewed are highly positive about the ProGauntlet and have either already pre-ordered it or are on the verge of buying it.

It is, on the other hand, unclear whether the ProGauntlet would have any value for other types of FMA. Therefore it is worthwhile to investigate this further, to find out what the actual size of the potential market would be.

Appendix 5: Introducing the ProGauntlet in the FMA market

According to the interviews, there is a clear interest in the ProGauntlet from certain FMA practitioners. It is important to know if the people that were interviewed are representative for the general FMA population. There is evidence that some FMA practitioners have been interested in the ProGauntlet ever since the start of its development, back in 2013. As a user on an FMA forum puts it:

"cool, they really should market this to the FMA community as well" - May 2013[7]

In this chapter, the value of the ProGauntlet in the FMA market is investigated.

Context

MANY DIFFERENT SYSTEMS

Filipino Martial Arts (FMA) is also known as eskrima, kali and arnis. The variation in nomenclature indicates the wide range of different interpretations of the martial art.

During FMA, a wide variety of weapons are used, in a combination of armed and unarmed techniques. There are dozens, or perhaps even hundreds of different styles all over the world. These different styles of FMA are called "systems". Different systems can use different weapons and training methods. The weapons can vary from wooden sticks to swords or machetes, and even items like broken bottles, credit cards and handkerchiefs.

FMA is not one specific sport, but an umbrella term that encompasses a huge range of different martial arts systems. This comment by a user on an online FMA forum about sums this up clearly:

"if there is one truth about Eskrima, it is that there are dozens (hundreds?) of systems […]. Even something as simple as the basic 12 strikes can be very different from system to system." [8]

In general, FMA is more focused on simulating combat situations that could theoretically happen in real life. This is one of the main elements that sets it apart from all other martial arts, which are usually focused on teaching specific techniques that are to be used in competition-style settings.

The wide range of different systems means that there is no standardized "official" type of FMA and no central association.

"HEAVY" SYSTEMS

A number of different systems have been researched, and it appears that the ProGauntlet would only be useful or valuable in the "heaviest" FMA systems. "Heavy" refers to the systems that focus on using metal swords and other edged weapons that can easily cause serious injuries to the bare hands.

[7] https://www.bullshido.net/forums/forum/traditional-martial-arts-and-styles-forum/123929-progauntlet-crowdfunding-the-ultimate-hema-hand-protection

[8] https://www.reddit.com/r/Eskrima/comments/irw7ou/noob_want_to_get_back_to_eskrima/

The FMA practitioners that were interviewed in-depth participated in such a system.

The people in this group think that about 75% of the FMA practitioners would be interested in the ProGauntlet. Their group consists of over 500 members, and according to them there are 10 to 15 thousand practitioners in the US in total. They think that the worldwide population consists of a couple of hundred thousand practitioners.

"In our group alone we have over 500 members. There are probably 10 to 15 thousand kali practitioners in the US and hundreds of thousands worldwide."

It is unclear if all these people follow the same system and if they would be interested in the ProGauntlet. During earlier research, CrossGuard has (very roughly) estimated that there are about 300 thousand FMA practitioners worldwide, but this covers *all* systems.

Looking at the great number of different systems, it is likely that many of these people follow other systems than Atienza Kali. The interviewees did say that their system differentiated itself from the "mainstream", in e.g. weapons, training scenarios and intensity of training.

The evidence doesn't suggest that (m)any other systems use the same types of metal weapons as the Atienza Kali system.

Apart from these estimations about the market size and need for protection made by the people from the Atienza kali system, there is no clear evidence that other systems need such serious protection as well.

NOT NEEDING HAND PROTECTION

After inquiring about this among other schools and systems, it appears that most people don't even wear hand protection at all. One owner of an Escrima (FMA) school in the Netherlands stated that his students usually don't wear protection at all, and that he has a couple of pairs of basic, padded gloves "just sitting in the closet" just in case he needs them during certain exercises. These padded gloves seem to provide enough protection already. He also couldn't recall any serious hand injuries among his students or other players. When looking at other sources, for instance photos and videos of FMA training, it seems that people barely even wear protection. If they do wear gloves, it are usually light sparring gloves with soft padding. This makes it difficult to believe that "hundreds of thousands of people" would want or need the ProGauntlet for FMA.

Other systems also claim that even light gloves are too restrictive. This would make it unlikely for the ProGauntlet to be useful:

"One of the biggest obstacles I have in finding adequate hand protection for me and my students is in locating gloves that allow a transition from grabbing a weapon to grabbing clothes (or a limb, or any other convenient handle). Most that I've found are either too clumsy to allow that easily (Lacrosse gloves, for example, tend to impede a quick snatch) or are […] dangerous to your partner (e.g. a grab attempt turning into an impromptu punch-with-a-metal-fist)." - 2013[9]

[9] https://www.reddit.com/r/Eskrima/comments/1fe5mz/progauntlet_gloves_for_weaponbased_martial_arts/

Examples of current FMA gloves

Kali Eskrima Gloves - V2

https://www.blaklist-gear.com/kali-hema-tolpar-gloves/kali-eskrima-gloves.html

€65

Gloves for sticks - Kali escrima, Kwon:

https://www.dragonsports.eu/en/36102-gloves-for-sticks-kali-escrima-kwon.html

€40

Playwell Full contact Deluxe Leather Escrima/Kali Gloves

https://www.amazon.co.uk/Playwlel-contact-Delxue-Leather-Escrima/dp/B07BSVRSSZ

€45

https://www.krakstorm.co.uk/krakstorm-full-contact-sparring-escrima-stick-gloves-fighting-kali-arnis-fma-jkd.html

€25

ORGANIZATION OF SYSTEMS

The FMA population appears to be divided into different systems, and within these systems, different groups are active. These groups are the main indication that there is at least some level of organization within the FMA population.

COMMUNICATION CHANNELS

Despite these groups, the FMA world proves to be difficult to understand and navigate for newcomers. Forums - often with outdated threads - seem to be the main source of information for many people, as well as various social media channels, mainly certain Facebook groups, certain YouTube channels and through Instagram. Online forums like Reddit are also used a lot by people to get in touch. On these forums, it people share training ideas, tips and other information. These channels are also used to communicate between and within the different FMA groups.

The practitioners that were interviewed said to have a leading role in the world of FMA/kali in the USA and beyond. They even offered to shoot videos of training and tutorials while wearing the ProGauntlet. The Atienza Kali Facebook page has over 4500 likes, and their YouTube channel has over 1800 subscribers.

If this group indeed has the leading role they claim to have, this would be a good way for CrossGuard to enter the FMA market.

“Heavy” systems - continued

The ProGauntlet only appears to be really useful for the types of FMA where the people use metal blades or other heavy weapons and engage in full-contact combat. Despite the lack of a central organization, there are some groups that have a greater amount of followers and a more prominent presence. Two of these systems are examined below.

ATIENZA KALI

Atienza Kali is a specific type of FMA that focuses on the use of “realistic” weaponry as they call it themselves. This includes metal swords, daggers, knives and other blades.

In FMA, people may engage in both armed and unarmed combat, or a combination of these. Atienza Kali is more focused on armed combat than other systems, according to themselves.

> *“We don't emphasize a lot of our curriculum on stick fighting, like a lot of FMA. We use aluminum training blades, which mimic swords or machetes blades.”*

The FMA practitioners that were interviewed are part of the this system, and they were highly positive about the ProGauntlet. Many of the previous insights about the use of the ProGauntlet in FMA are based on the perspective from this system.

DOG BROTHERS MARTIAL ARTS

Another system that was researched is called "Dog Brothers Martial Arts” (DBMA). This is an international community that appears to have a leading role in the world of martial arts and self defense. Their own group has over 350 official members (shown on their website) and an international presence as well.

This system positions itself as being on the rough side of FMA, with a mix of stick fighting and unarmed combat techniques. Their slogan is *"Higher consciousness through harder contact"*[10].

DBMA appears to be more representative for the more mainstream types of FMA, albeit on the rougher side of the spectrum in terms of physical contact. It also includes techniques like grappling and punching. According to a representative of DBMA, they specifically choose not to wear very thick, protective, hard shell gloves because their fights transition from armed to unarmed combat seamlessly. The battles often continue even if a helmet falls off, so it is important that the glove doesn't pose a danger to the opponent.

"Broken bones are not too common because one is more cautious when sparring with lighter gloves and exchanging blows."

"I am unsure that much protection is required for normal stick fighting."

Funnily enough, the type of Filipino Martial Arts that requires serious hand protection does not appear to be practiced in the Philippines.

Other types of FMA often have much less hard, direct and intensive physical contact than Atienza Kali and DBMA, so therefore they don't seem to need much protection. This might truly the case, or it might be invisible for outsiders in the FMA world. Either way, the impermeability of the market, the large variety of different systems and the lack of similar competitors makes it unlikely for the ProGauntlet to be successful in the the "general" FMA market.

[10] http://dogbrothers.ch/dogbrothers/origin/

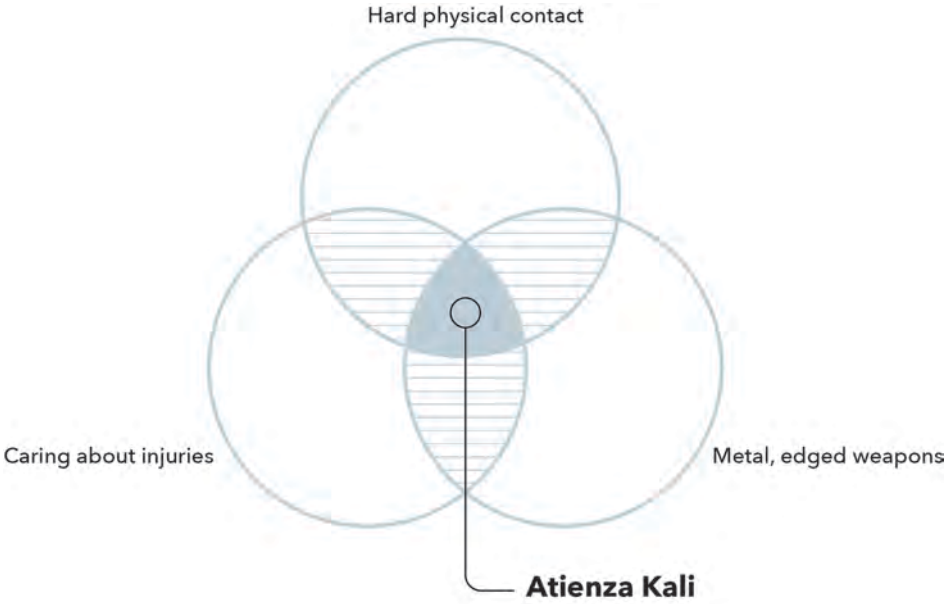
COMPATIBLE SYSTEMS

Of all the styles that were researched, there appears to be only one style that fits the ProGauntlet in terms of needs and use cases: the Atienza Kali system. This is the only system that has voiced a clear need and desire for the ProGauntlet. There is no evidence that other systems would benefit from such a glove.

"We definitely deal more in a realistic type of training. So to get to that realistic type of training and to be safe, you need protection."

"Those other systems are more drill-focused. Therefore they don't need all this protection all the time, because they're not really hitting each other. We [in Atienza Kali] try to hit each other. Yeah, that's really the difference. That's why we need protection."

Photo credit: Atienza Kali



Market size

The people from Atienza Kali claim that there are 10 to 15 thousand practitioners in the USA, of which 75% would be interested in the glove if it proves to be as useful as expected. Worldwide, they say that there are "hundreds of thousands" of practitioners.

Inquiries into other systems contradict these estimations of the market size, and have shown that hard, full-contact combat with metal blades appears to be only a very small subsegment of the total FMA population.

The apparent need for better protection as described by the Atienza Kali people isn't seen in other types of FMA. In a lot of systems, people don't seem to wear hand protection at all, or only during specific exercises. As mentioned earlier, this was confirmed by the owner of a FMA school in the Netherlands. According to this same person, only a very small minority of people practice FMA at such high intensity with metal blades. This notion that the current hand protection is adequate was also confirmed by other systems.

CONCLUSION

Based on the research, the only segment of the FMA market that would clearly benefit from the ProGauntlet, is the group of people practicing Atienza Kali. Other types of FMA do not appear to gain much from the level of protection that the ProGauntlet offers, and the glove would probably even increase the risk of injuring others, due to the use of unarmed combat techniques.

In conclusion, the "segment" of the FMA market for which the ProGauntlet can be useful, is likely only a small niche of around 500 users.

Photo credit: Atienza Kali

Consumer

Atienza Kali: A group of FMA practitioners that use a variety of

different weapons, often metal blades, and want to practice without holding back. They need as much protection as they can possibly get, while still being able to move as freely and naturally as possible.

They have a lot of experience with hand injuries and are actively looking for ways to minimize these injuries, in order to keep on training.

According to themselves, they are "at the forefront of realism", when it comes to combat training. This means that they use metal swords and they want to hit their opponents like they mean it. They want to train as hard as they can, for as long as possible. To achieve this, they need proper hand protection. They actively search for better equipment and often come up with DIY solutions for their problems. Practitioners mentioned that they modify existing protection and/or combine different types of protection to fit their needs.

When comparing this behavior to the model for diffusion of innovations by Rogers, most Atienza Kali practitioners would fit in the description of innovators [29]. They are likely to try new innovations such as the ProGauntlet straight away, rather than waiting for the product to gain popularity.

The practitioners seem to be motivated by incentives of self-defense, and this is reflected by their training methods. They train certain scenarios instead of technical drills. The scenarios appear to be quite extreme for a realistic self-defense class (unless people would carry a machete with them every day), so it is unclear to which extent these techniques are designed to be used in real life. The scenarios are likely a way to improve one's abilities through simulating an extreme situation, so that they are ready for any other situation, whatever that might be.

LOCATION

The group consists of over 500 people, divided over 25 training locations, most of which in the USA. According to the members, the number of training locations is increasing, as well as the total number of members.

Most of these people appear to be centralized in a couple of areas. The regions around New York and in southern California they seem to have the greatest amount of practitioners, judging by the number of training sites in these areas. Other training sites are found in South Carolina, Georgia, Florida and Texas. The only training site outside the USA is found in Ireland. [11]

[11] https://atienzakali.com/locations/

Photo credit: Blaklist Gear

Besides these fixed training locations, the instructors also teach on any other location in the USA, in the form of seminars and workshops.

Competitors

There aren't many direct competitors within the product category of FMA / kali / escrima / eskrima / Arnis gloves. The few gloves that are listed under these names are completely different from the ProGauntlet, and mostly feature light padding and an open palm.

For the "heavy" FMA gloves, the main competitor is actually the same as in the HEMA market, namely the SPES Lobster Heavy gloves (appendix 1). Besides these gloves, the people from Atienza Kali wear all sorts of different types of gloves, including ice hockey gloves and lacrosse gloves.

Atienza Kali practitioners are used to wearing equipment that isn't specifically made for their activity. They mentioned that they often alter existing equipment, in a DIY fashion. This indicates that they are already quite open to exploring less common solutions, inspired by different markets.

Promotion & sales

According to the respondents, they already buy their equipment through the reseller that CrossGuard already has in the USA. In this case, CrossGuard doesn't need to change anything in order to provide for these people.

In short, only the Atienza Kali people seem to be seriously interested in the ProGauntlet, and they already buy their equipment through the exact same reseller that CrossGuard already has in the USA.

"If [the ProGauntlet] offers the protection we think, all of our members would get them."

As this network already has access to the current sales channels of the ProGauntlet, it does not seem to make a lot of sense to change that.

One recommendation for CrossGuard could be to request the reseller to put the ProGauntlet on the webpage for FMA equipment as well. As of now, it is only shown in the category of HEMA gear, so FMA practitioners need to actively look for it. If it would be listed under FMA gear as well, it would be easier to find for these users.

BRANDING

As the context of use of FMA is so closely related to HEMA, these people are essentially "free" extra users for CrossGuard. People's reasons for buying the ProGauntlet would be virtually the same as in the HEMA market, so it would not be necessary to rebrand or reposition the product.

EUROPEAN MARKET

There is no clear evidence of the existence of another FMA group with a style similar to the people from Atienza Kali. The apparent absence of metal weapon-based FMA groups outside of the USA makes it unattractive put resources into the FMA market in other continents. CrossGuard's own website can cater to the limited number of European FMA practitioners that might be interested.

If, however, there does appear to be a demand in Europe after all (which is not expected based on the research), there is a possible reseller in France that CrossGuard could contact. This reseller is an online store that sells equipment for a wide range of martial arts. This includes HEMA equipment and other types of FMA equipment, such as fighting sticks. On their website they mention that they sell gear for "uncommon and demanding fighting arts"[12]. Among their product range, they have a number of gloves that compete directly with the ProGauntlet, such as the SPES Lobster Heavy gloves and the Red Dragon HEMA gloves, shown in appendix 1. In their FMA product range they even sell Bauer ice hockey gloves. The only protection that they sell which is specifically made for FMA are the "Kali Eskrima gloves V2". This looks like a lightly padded glove with an open palm, very different from the ProGauntlet.

This could be an optional reseller in the event that a group similar to Atienza Kali emerges in Europe in the future.

PRICE

Since the ProGauntlet can be sold through the exact same reseller as for the HEMA market in the USA, the price should stay the same.

The amount of money that Atienza Kali practitioners spend on gloves has increased over the years, according to one of the interviewees. In the beginning they would buy ice hockey gloves of around $60 per pair, and now they spend up to $200 on the SPES gloves. $450 for the ProGauntlet is arguably a big step up, but a selling point for the ProGauntlet would be its versatility for their training: now they use around two or three different types of gloves, depending on the situation. Since the ProGauntlet has the flexibility of lightweight gloves and better protection than all of the heaviest gloves that are available, it removes the need for having multiple pairs of gloves.

" if you could use it in light sparring, but and it still offers the enough protection when you go to heavy sparring, or more hard contact, then then that's a pretty good glove. Yeah, then I don't have to switch between two or three different gloves."

[12] https://www.blaklist-gear.com/kali-hema-tolpar-gloves/

SIZING

Since the number of FMA practitioners that will buy the ProGauntlet is likely not greater than 500, it would not make much sense to invest in optimizing the product for this market. This also applies to the sizing of the glove. If CrossGuard decides to make multiple sizes for the HEMA market, then these can also be sold in this market, but the number of potential users in the FMA market alone is too small to justify sizing options.

Conclusion

FMA seemed like an attractive market for the ProGauntlet in earlier research, but after further investigation the market appears to be much smaller than expected. Instead of being representative cases for the whole market, the participants of the interviews seem to be outliers, who practice a type of FMA that is not considered mainstream.

Although there is some level of organization within the FMA population, is is definitely not a widely known, standardized and/or regulated sport. There are (almost) no clear, centralized sources of information on FMA, which likely has to do with the fact that there is no such thing as an "official" type of FMA. This makes it very difficult to navigate through all the information without being part of a group.

Most groups appear to have their own interpretation of the martial art, which creates a large variance in needs among the different groups. Without a central organization, communicating with all different (sub-)groups can be challenging and time-consuming.

Based on the research done during this project, it appears that only the so-called Atienza Kali group is really interested in the ProGauntlet. These people have voiced a strong desire to buy, test and review the ProGauntlet, but other groups and systems apparently don't need such hand protection.

Estimations about the market size, made by the people that were interviewed, don't appear to be a realistic representation of the actual number of people that would be willing to buy the ProGauntlet. Allegedly, there are 10 to 15 thousand FMA practitioners in the USA and "hundreds of thousands" of practitioners worldwide, but the available evidence doesn't suggest that many of these people would be interested in the ProGauntlet.

The members of Atienza Kali are likely the only ones who would actually be willing to buy the ProGauntlet, as they are the only known system that would clearly benefit from it. That comes down to around 500 people.

The members who were interviewed appear to be quite well-connected in the FMA scene in the USA and have also offered to help promoting it within their network. As this seems to be the only other market/niche in which the ProGauntlet can be sold without making any changes to the design, it is highly advisable for CrossGuard to maintain this contact, in order to sell as many pairs of gloves as possible in this niche of the FMA market.

There is still a chance that a redesigned glove could be useful for other types of FMA, but due to the aforementioned variance in techniques and needs of different groups, it seems unlikely that CrossGuard can design a single glove that meets the needs of different systems all at once. The lack of standardization makes it an unattractive market to develop a product for.

Of course the ProGauntlet still needs to be tested within this market. This testing may result in uncovering some essential design changes. The aim of the performed research is to make this risk as little as possible, but it cannot fully guarantee the real-world product performance in the given market. The level of enthusiasm about the ProGauntlet that has been expressed by the Atienza Kali practitioners suggests that the ProGauntlet will be highly valuable for them.

Appendix 6: competitors in the field hockey market

Adidas:

"we believe that, through sport, we have the power to change lives"

"We push the boundaries of products, experiences and services to drive brand desire and capitalize on the growth opportunities"

"we work every day to inspire and enable people to harness the power of sport in their lives."

https://www.adidas-group.com/en/group/strategy-overview/

Osaka

They want to sell an *experience* through their products, according to themselves. Wants to promote a sense of community Inspired by Japanese products; high tech and good-looking. Minimal, clean and functional. More modern than the competitors. "The new kid on the block."

They tried to design a new type of glove, but failed and settled for a conventional design.

"Hockey is our DNA, it's our core, our heritage. Our mission was to create **durable, premium products with refined design sensibilities. We care for perfection in every product we manufacture."**

https://www.hockeypoint.nl/nl/brands/osaka/

https://osakaworld.com/pages/about

Osaka sells all types of hockey gear and as a part of their lifestyle brand, they also have collaborations with other companies, such as KLM airlines.

Osaka and The Indian Maharadja both have an "east meets west" position, where they try to tie themselves to the design and culture of Japan and India, respectively.

For none of the brands, the gloves are at the core of their brand. Osaka for instance lists their gloves as "accessories"

The Indian Maharadja

High quality, for experienced players

"Lifestyle field hockey brand, founded in Amsterdam in 2009."

"The Indian Maharadja supports athletes in achieving their personal goals by maintaining high quality products and innovation and by expressing sensation with distinctive designs."

https://www.indianmaharadja.nl/about-us

Brabo:

"Everyman"

"Innovative technology, extensive stick collection, trendy designs […] In short, there is a suitable stick for every player."

"Brabo sticks are made of high quality materials. These materials contribute to excellent playability. This is also the reason why many national and international top players have chosen Brabo Hockey."

https://www.brabohockey.com/en/about/

Dita:

High-tech, one-stop shop

Grays:

"Everyman"

Functional, no-nonsense, maximum padding/protection gloves

Gryphon:

High-tech, carbon technology, founded by a physicist

"The G-Mitt pro is the ultimate hockey glove"

They proudly show their technologies on their website. They are a highly engineering/tech/composite-focused company

https://www.gryphonhockey.com/our-story

https://www.gryphonhockey.com/techonology

Naked

"We believe nothing should come between you and your performance on the pitch, so after we created the world's best hockey stick, that's exactly what we added: nothing."

https://nkdhockey.com/pages/naked-manifesto

Reece:

"MISSION – WHAT WE STAND FOR

To make you perform at your best.

VISION – WHAT WE AIM FOR

To bring the best performance into active lifestyles.

VALUES – WHAT WE BELIEVE IN

Passionate about sports"

TK:

Very high-tech sticks, large heritage.

Already has a glove with a hard outer shell on the knuckles/back of the hand. Their gloves don't get as much attention as their sticks. Both in technology and in description on their website.

https://www.tk-hockey.com/en/technology

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