ViS

Product report

MSc04-ID04 | Aalborg University | 2018

Allan Gram Pedersen & Angela Lise Frank

Title page

Team	MSc04-ID4
Title	VIS
Theme	ESport injuries
Project period	01/02/2018-13/06/2018
Main supervisor	Finn Schou
Co-supervisor	Ewa Kristiansen
Pages	21
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Abstract

The project revolves around the design of a hand training device aiming to reduce the risk of developing hand injuries of eSport players thus prolong their career. The product is connected to a computer application where the user can follow hand exercises. The mechanism has a spring for each digit that is connected straight to the fingertips with a rod; this goes through guides placed on the phalanges to transmit the forces along the digits. The strength of the resistance is changed by changing the spring units. The exercises are gamified by the computer application with which the users can check their progress day by day, start training, share results with other users, and also play a minigame alone or with friends. The product is produced in collaboration with Technogym who is a logical partner as they already make training equipment both for gyms and home use and they are covering sports like golf and Formula 1. This makes them a candidate for Vis to help them getting into the eSport market.

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Introduction

Vis is a master thesis project of Industrial Design revolving around the development of a hand training device for eSport players called Vis Gauntlet. The word *vis* means strength or willpower in latin, and gauntlet refers to a strong armored glove used in medieval times. The product has been developed with insights from players of all levels who were met at events. Medical professionals were also contacted throughout the process to validate developed concepts.

When playing video games competitively, the body of the players is subjected to demanding requirements: this causes strain, and in the end injuries and musculoskeletal disorders such as carpal tunnel syndrome. Those injuries can get so severe they force the players to take long leave of absence to recover; in the worst cases the players are forced to retire and quit their career. The Vis Gauntlet addresses these issues by prevention. By using the product, the players would reduce the risk of developing injuries in their hand through exercises that help keeping balance between the extensor and flexor digitorum, and relieving the tension build up in the hand during a game. The Vis Gauntlet motivates the player to exercise through gamifying the exercises in a software program which let the players working out, play, compete and share results.

ESport

Competitive video gaming, also known as eSports, are a kind of sport where players compete by using electronic devices. Although it is a common opinion that eSport is not a true sport because the player competence is not measured in physical skills, competitive video games can be very demanding for the body due to the need of high response speed, hand-eye coordination and fast movements.

The eSport scene is growing fast: it is estimated that the global eSport economy will reach up to $905.6 million in 2018. ESport has also a direct influence on hardware sales.

There are 22,6 million eSport enthusiasts in Western Europe. The popular eSport game Counter-Strike: Global Offensive (CS:GO) is one of the most popular in Denmark: 10% of total worldwide CS:GO professional players are Danish, while there are around 132 275 casual danish players. Some of the hardcore players are so devoted to the game they practice up to 10-13 hours per day.

Injuries

Injuries in eSport are not uncommon, but teams lack medical staff and often players ignore the pain to keep playing. Due to long use of computer, rapid and repetitive finger movements when using a mouse or a keyboard, they can develop musculoskeletal disorders like Carpal Tunnel Syndrome. Many players stopped their career suddenly due to those injuries once the pain became unbearable. To prevent those injuries, some medical professionals recommend specific hand exercises, though the professional players don't do them. *Vis* is intended to improve those hand exercises by giving additional force resistance and motivating the players by gamifying the experience.

"Injuries in esports are going to become an economic burden. Health benefits in player contracts isn't common." Thiemo Bräutigam

"Without medical staff, the players lack protection from injuries that have already ended or shortened multiple careers." David Wiers

"Before my injury I did not exercise my hand. After I did hand exercises while I had the pain but now I rarely do them. I should."
Stephanie "MissHarvey" Harvey


VIS
VIS

The product

The Vis gauntlet is a training device for the hands which reduces the risk of hand injuries in eSport players. Vis motivates the eSport players to do exercises recommended by medical professional by gamifying the experience.

Vis is a gauntlet providing resistance to train the hand muscles. At the end of the resistance mechanisms there are distance sensors connected to the computer via USB cable; a software program tracks the movements thus the exercises executed. Through the app, the user is guided while doing hand exercises, they are able to compete with friends, check and share results with other users. The product comes with three different levels of resistance that the user can change in between.

It takes few minutes to exercise - this can be done while waiting for the next game match to load. Other than applying the resistance individually to each digit, the product offers a range of different exercises while existing products on the market, focus on single exercises.

The sportive aesthetic and audacity of colors inspired by CS:GO characterize the product.

Target group

The Vis gauntlet is a hand exerciser for eSport professional players who want to keep their performance at high level while taking care of their hand muscles, and in general for all eSport players who want to increase their hand dexterity. Vis will accompany eSport players through their career while helping them in keep their performance high.

22,6 MILLIONS

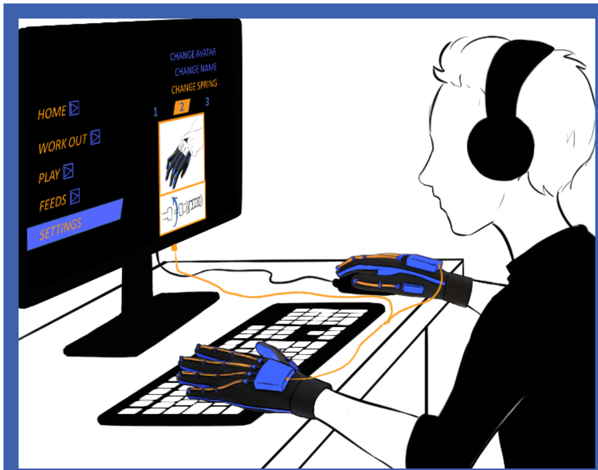
ESPORT ENTHUSIASTS IN WESTERN EUROPE (2018)


ESL
DXRACER
dafabet
VIS
NITOR

Use of product

1 The user is playing his favourite game when the match ends.

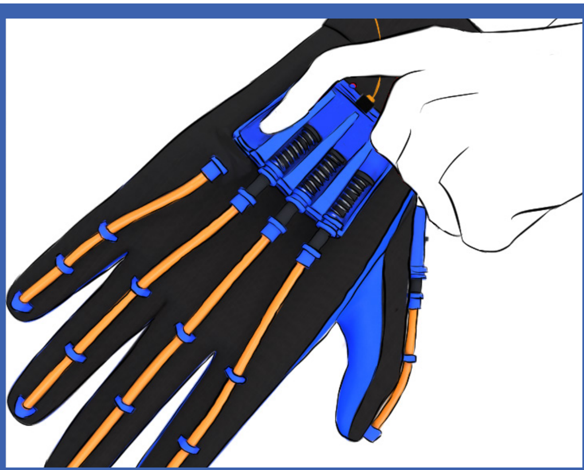
2 While waiting for the next match to start, the user puts on the Vis gauntlet.



5 The user sets the chosen spring resistance in the program.

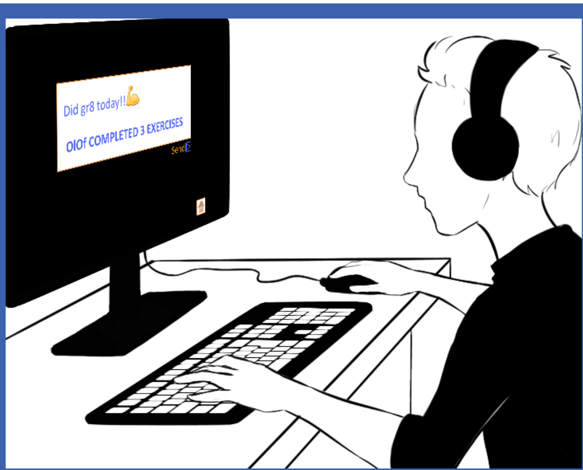
6 The user does exercises.

3 The user follows the training program.



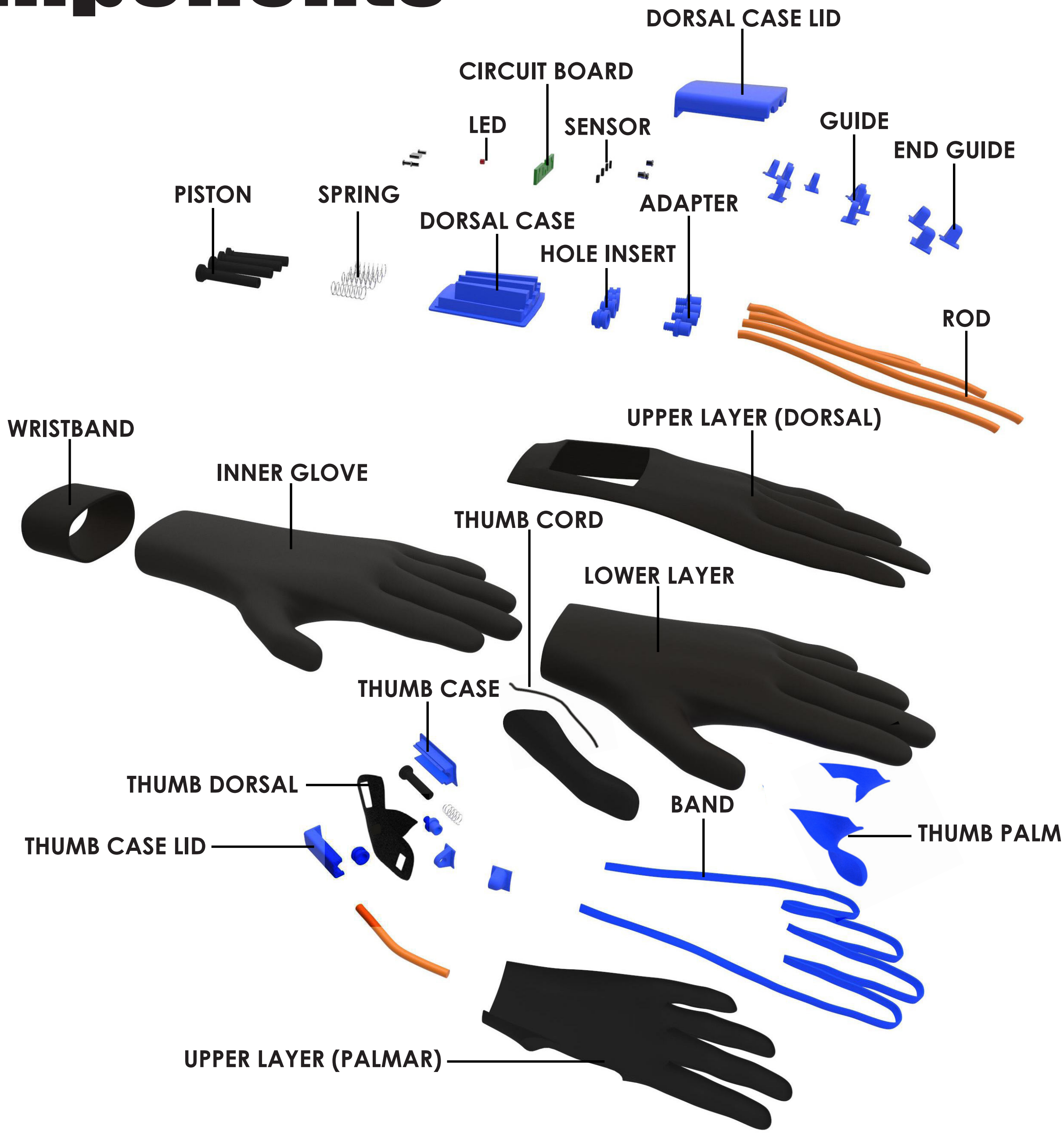
4 The user changes the spring resistance, takes off the currrent spring unit and put on another one.

7 The user decides to play the Vis gauntlet game.

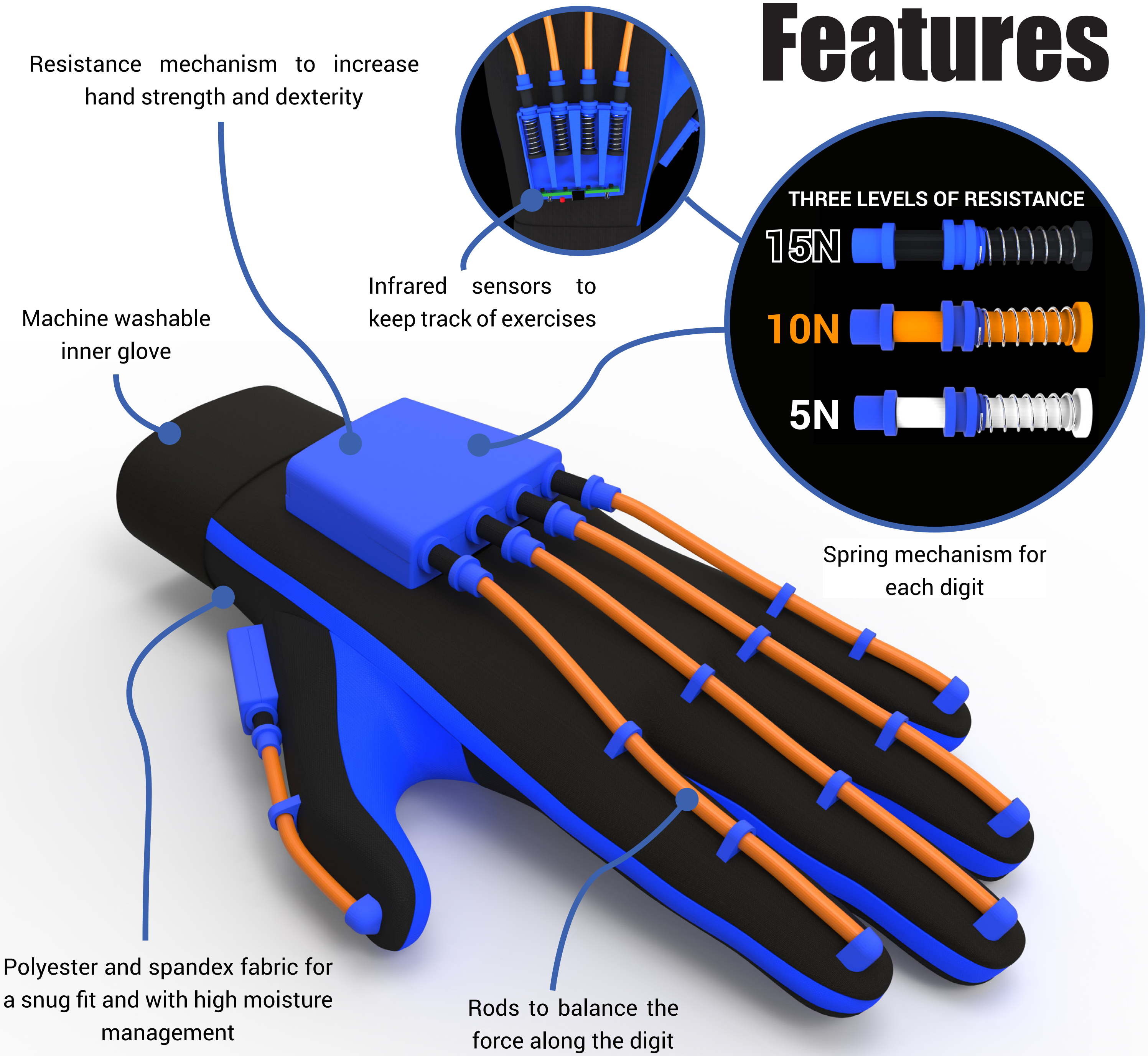


8 At the end, the user takes off the glove and shares the results with his friends.

Components


DORSAL CASE LID
CIRCUIT BOARD
LED
SENSOR
GUIDE
END GUIDE
PISTON
SPRING
DORSAL CASE
ADAPTER
HOLE INSERT
ROD
WRISTBAND
UPPER LAYER (DORSAL)
INNER GLOVE
THUMB CORD
LOWER LAYER
THUMB CASE
THUMB DORSAL
BAND
THUMB PALM
THUMB CASE LID
UPPER LAYER (PALMAR)

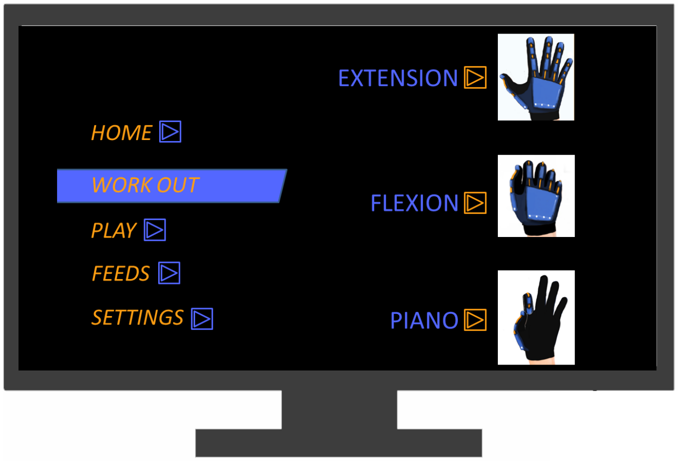
Features


Resistance mechanism to increase hand strength and dexterity
Infrared sensors to keep track of exercises
THREE LEVELS OF RESISTANCE
15N
10N
5N
Machine washable inner glove
Spring mechanism for each digit
Polyester and spandex fabric for a snug fit and with high moisture management
Rods to balance the force along the digit


EXERCISE!
5 FLEXIONS
next
SAMSUNG
VIS

The program

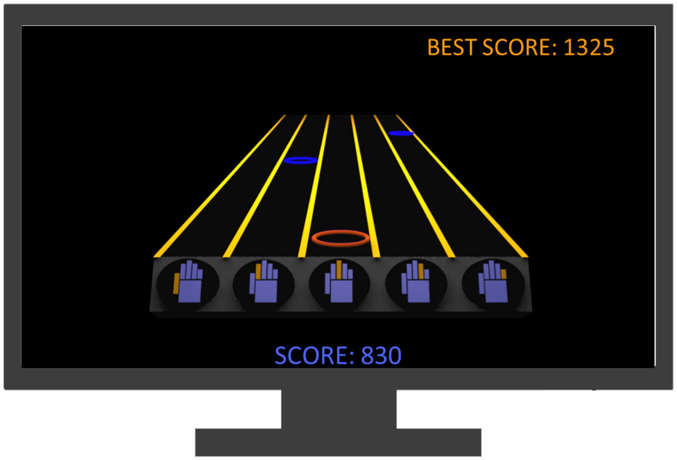
The Vis gauntlet is connected to a computer application via USB cable. The program motivates the eSport players to do hand exercises by making it easy and fun. In the program, the player can do hand exercises that are shown on the screen and are tracked making the user able to follow the progression. The user can also share the results of the training to friends and follow them through the newsfeed.

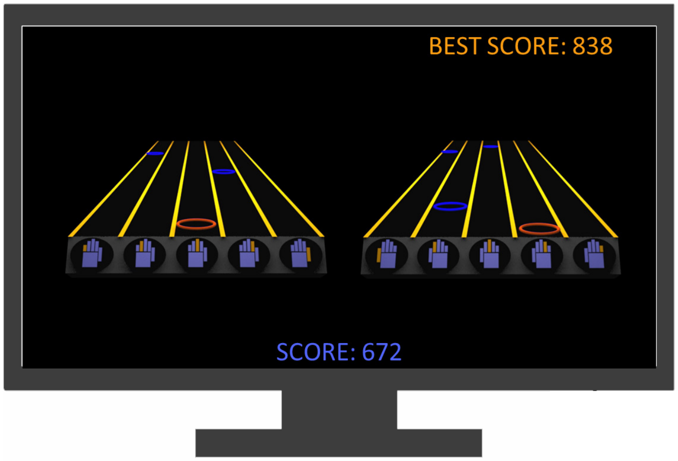


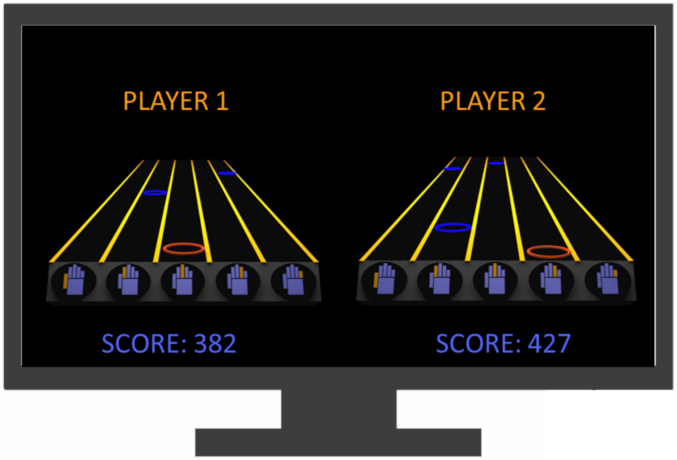

ProLite E2773HS
BEST SCORE: 838
SCORE: 672
iiyama
TOTAL WAR
ViS

The game

In the program, the user can find a minigame to train the flexor and extensor muscles while having fun. The minigame is inspired by rhythm games like Guitar Hero. The game map is divided into lanes for each finger where objects will appear. The player then has to time the flexion or extension of fingers to when the objects get close and change colour. Depending on how well the player time the finger movements, they will score points. Either the user will play alone and try to beat their own score or play together with a friend and compete. The game can either be played using one hand or both hands having separated symbols and timings which adds another layer of difficulty.

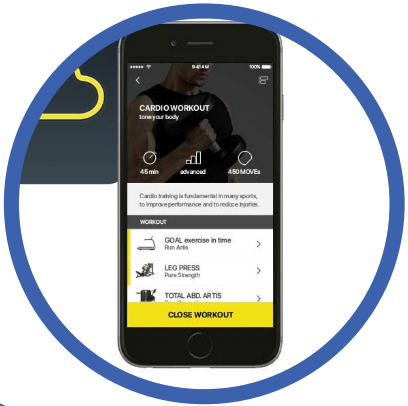






HOME EQUIPMENT

FITNESS APPS



GYM MACHINES

Partnership

The Vis gauntlet is developed by Vis, a small design company collaborating with Technogym, a company focused on promoting wellness through fitness. Technogym is a global leader in the fitness market producing fitness equipment, but they also work on medical-scientific innovation and social projects. Technogym was the exclusive official supplier of the Rio 2016 Olympic Games, and they are partners with teams from all kind of sports such as Ferrari, Paris St. Germain, and Alinghi. With such a varied interest in wellness for every kind of sport, the VIS Gauntlet can help them get wellness and Technogym into eSport.

Budget

SOLD PAIRS OF GLOVES

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Units sold	3100	4750	6750	4250	3750
Sales price	691,77	691,77	691,77	691,77	691,77
Royalties 8%	123.903,47	189.852,10	269.789,82	169.867,67	149.883,23
Maintenance	-95.400,00	-95.400,00	-95.400,00	-95.400,00	-95.400,00

ASSET SALE - MECHANISM

Units of 10 sold	310	630	913	763	588
Sales price	54,01	54,01	54,01	54,01	54,01
Royalties 8%	1.041,78	2.117,17	3.066,54	2.562,45	1.974,35

BREAKEVEN ANALYSIS

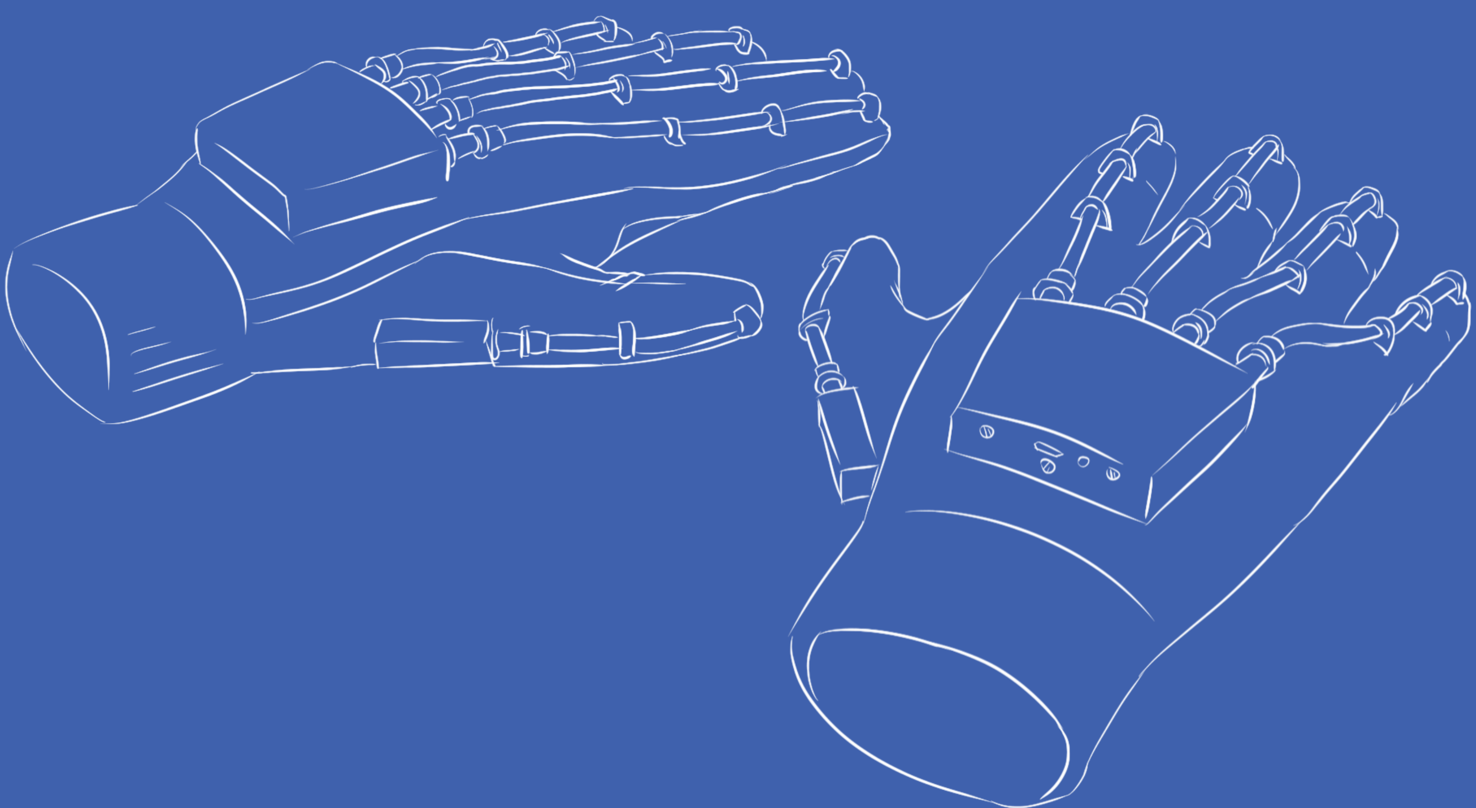
Investment	-284.200,00	-254.654,74	-158.085,48	19.370,88	96.400,99
Contribution margin	29.545,26	96.569,27	177.456,36	77.030,11	56.457,58
REMAINING	-254.654,74	-158.085,48	19.370,88	96.400,99	152.858,57


WWW.NIP.GL


EIZO
NINJAS IN PYJAMAS
WWW.NIP.G
V!S

ViS

VIS



Process report

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Title page

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Preface

The project presented in this report is a 4th semester Master Thesis project in Industrial Design at Aalborg University carried out by group MSc04 ID4. The project spans from February 2018 to May 2018. The theme of the project is eSport injuries. The design process has been an iterative process.

Abstract

The project revolves around the design of a hand training device aiming to reduce the risk of developing hand injuries of eSport players thus prolong their career. The product is connected to a computer application where the user can follow hand exercises. The mechanism has a spring for each digit that is connected straight to the fingertips with a rod; this goes through guides placed on the phalanges to transmit the forces along the digits. The strength of the resistance is changed by changing the spring units. The exercises are gamified by the computer application with which the users can check their progress day by day, start training, share results with other users, and also play a minigame alone or with friends. The product is produced in collaboration with Technogym who is a logical partner as they already make training equipment both for gyms and home use and they are covering sports like golf and Formula 1. This makes them a candidate for Vis to help them getting into the eSport market.

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When playing video games competitively, the body of the players is subjected to demanding requirements: this causes strain, and in the end injuries and musculoskeletal disorders such as carpal tunnel syndrome. Those injuries can get so severe they force the players to take long leave of absence to recover; in the worst cases the players are forced to retire and quit their career. The Vis Gauntlet addresses these issues by prevention. By using the product, the players would reduce the risk of developing injuries in their hand through exercises that help keeping balance between the extensor and flexor digitorum, and relieving the tension build up in the hand during a game. The Vis Gauntlet motivates the player to exercise through gamifying the exercises in a software program which let the players working out, play, compete and share results.

Acknowledgements

During the design process, we relied on professionals to gain insights. We would like to thank the following people for sharing their knowledge:

Technical Engineer René Hagelund Foldager for giving us technical support while researching on springs, and the tour at Hagens Spring Group.

Biomechanical professor John Rasmussen at M&P Aalborg University for the help in the early stage of the process, which was fundamental to understand possibilities and limitations of working with hand problems.

The medical professionals Anne-Sofie Høy and Caitlin McGee for helping to specify and verify the concepts in relation to anatomy and hand injuries.

Martin Højen Grøn and Henrik Lajgaard for allowing the team to visit their events and interview the players.

The CS:GO Team coaches Emil Sørensen, Jakob Larsson, Lasse Kjaer and members of the Cocoon eSport community for the insights regarding the eSport scene and their players.

Professional CS:GO player Stephanie Harvey for helping us to understand the problem from a player perspective.

Thanks to all the players who helped through the process by answering our questions and participating to the tests.

Reading guide

It is advised to read the material in the following order:
Product Report
Process report + appendix
Technical drawings

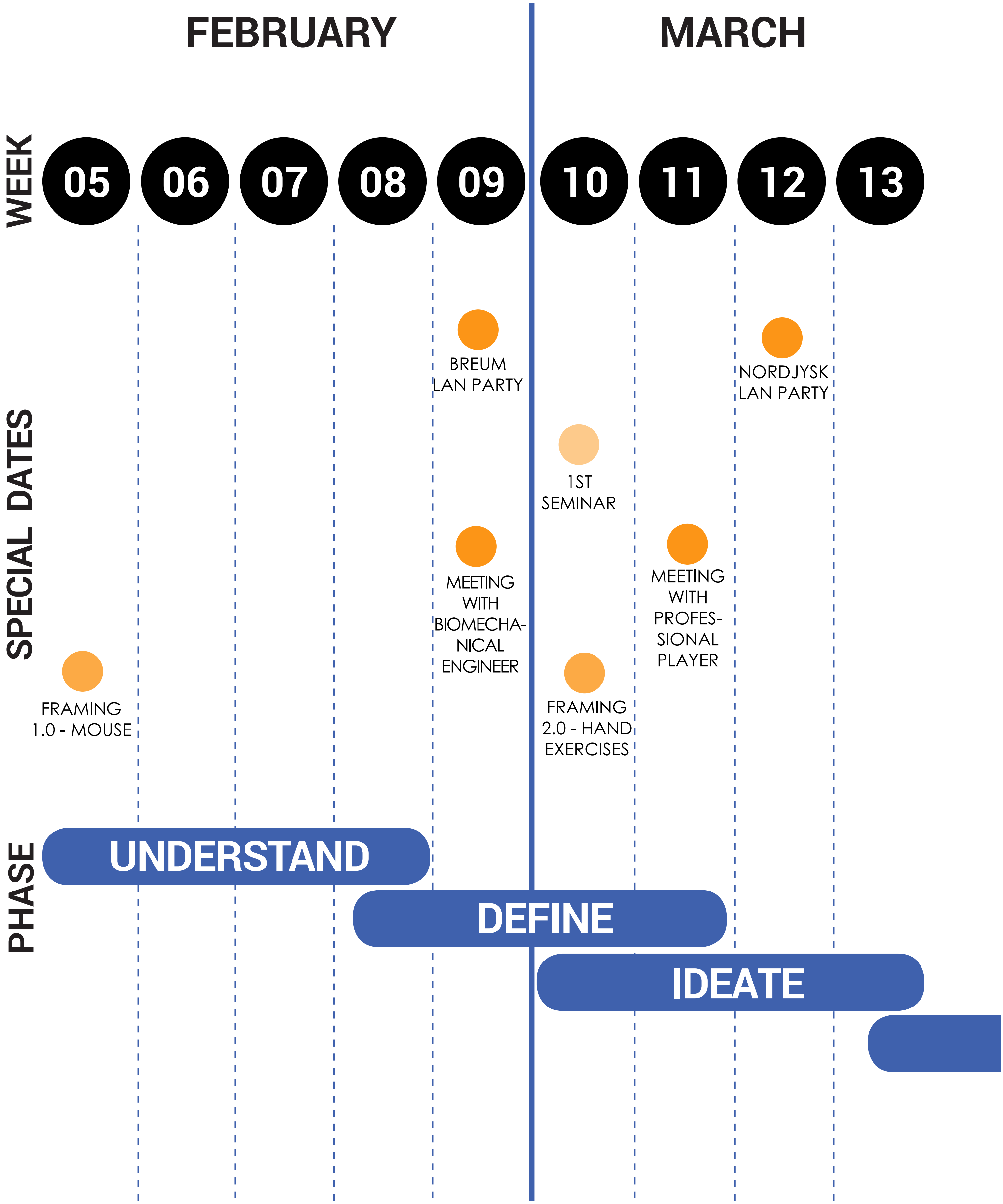
The product report is set up to showcase the final product where the process report shows how this results was reached.
The process report is divided into eight chapters:
Understand: Investigation of the subject
Need: Investigation of problems to find a need
Define: Definition of the project direction
Ideate: Ideation to find the visual direction for the product
Development: Development of the product solutions
Detail: Detailing the product
Implement: Implementation plan for introducing the product to the market
Epilogue: Project outro
References are listed by the Harvard reference system: (Lastname, Year). When the reference is placed before a period it refers to the paragraph. Illustration number is referred as: Ill. (Page number, Illustration number). Appendix x.x refers to the appendix found in the binder. In the process report, small boxes will appear while reading. These will give an overview of the most important conclusions on the section.

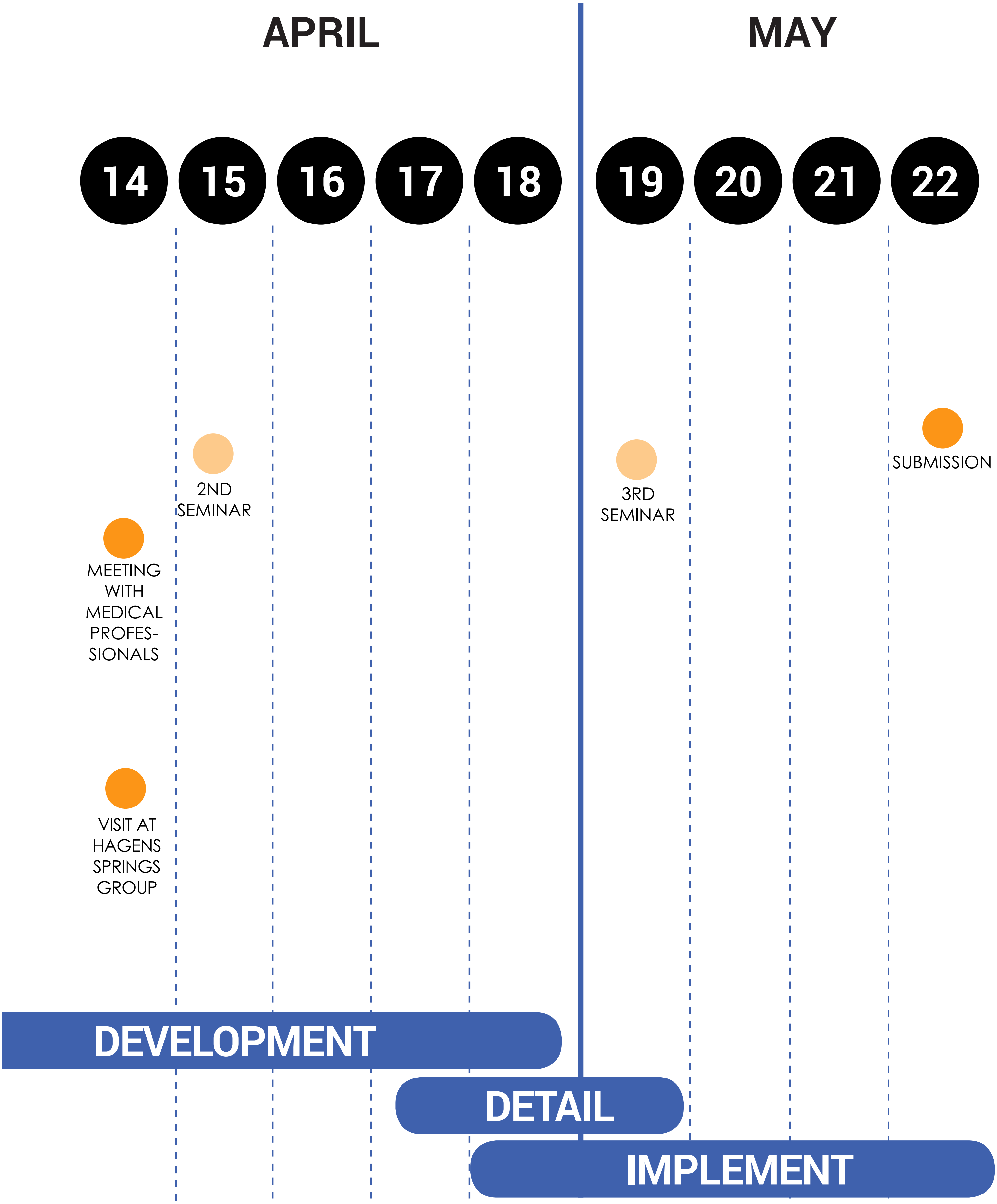
▲ **new insight**

! **needs more knowledge**

▼ **disproved hypotesis**

Process tracking




APRIL
MAY
14
15
16
17
18
19
20
21
22
2ND SEMINAR
SUBMISSION
3RD SEMINAR
MEETING WITH MEDICAL PROFES-SIONALS
VISIT AT HAGENS SPRINGS GROUP
DEVELOPMENT
DETAIL
IMPLEMENT

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Ill. 7.1

1 UNDERSTAND

In this section the eSport scene is explored through desktop research, interviews and observations made at Breum and Nordjysk LAN party. The problem of injuries in eSports is unfolded to understand what causes them and where are the issues with the current solutions.

1.1 ESport

What is eSport?

The term eSport (electronic sport) refers to competitive video gaming. In other words, eSport is a kind of sport where the players compete by using electronic devices such as computers, consoles or similar in tournaments often sponsored by business organisations. In the last years, eSports have grown rapidly also thanks to online games and online broadcasting technologies. It is a common opinion that eSports can not be called a sport because the player competence is not measured in physical skills; though the body and physical activities cover an important role in the eSport scene. (Hamari and Sjöblom, 2017)

Ill. 8.1 *Professional player at eSport event*

Body involvement in eSport

Reaction time and fast, controlled movements are often crucial to win a match: when playing competitive, it is necessary having good hand-eye coordination and response speed. When playing, there are also more unapparent engagements of the body such as pressure, rhythms and intensity of the gameplay and play context. (Witkowski, 2012)

According to a research study conducted by Dr Dominic Micklewright of the University of Essex, players have a reaction speed close to that of jet pilots. (ACSH Staff, 2016)

A game like Counter Strike or League of Legends is demanding for hand-eye coordination and requires a high level of strategy. Ingo Froböse, professor at the German Sports University in Cologne, said: "The eSports athletes achieve up to 400 movements on the keyboard and the mouse per minute, four times as much as the average person. The whole thing is asymmetrical, because both hands are being moved at the same time and various parts of the brain are also being used at the same time." (Martin Schütz, 2016) Scientists at the German Sports University College measured the heartbeat rate of professional players. During specific intense game phases, it has been noted to reach short bursts of intense activity, usually between 160 to 180 BPM. (Martin Schütz, 2016)

160-180 BEATS PER MINUTES

REACTION SPEED AS HIGH AS A JET PILOT

HIGH HAND-EYE COORDINATION

ESport requires body involvement

Injuries in eSport

Now it is establised the physical strain imposed on eSport players, it is easy to see how, as every other athlete, they too can be subject to injuries. John Svärd, a chiropractor at the Kroppshälsan clinic in Sweden, points out that it is a common misconception that gamers, when sitting in front of a computer, are not using their muscles and are just relaxing. When players are sitting and focusing on the game, they have a lot of tension in their upper body. The muscles and tendons are tensed for a long time, and the blood can not flow properly through them because the body is stiff. Injuries in eSports are no exception, and the pain experienced is similar to that afflicting office workers. (Mashable, 2017)

On eSport injuries, Levi Harrison, an Orthopedic Surgeon dealing with this problem, says: “Every game has a specific type of stress and its own intrinsic issues. It’s individualized to the gamer as well as the game. If the gamer is using a keyboard, there are often problems with the wrist, elbow and fingers. If the gamer is using a controller, his or her thumb is the major digit that takes the hit.” (Kevin Wong, 2017)

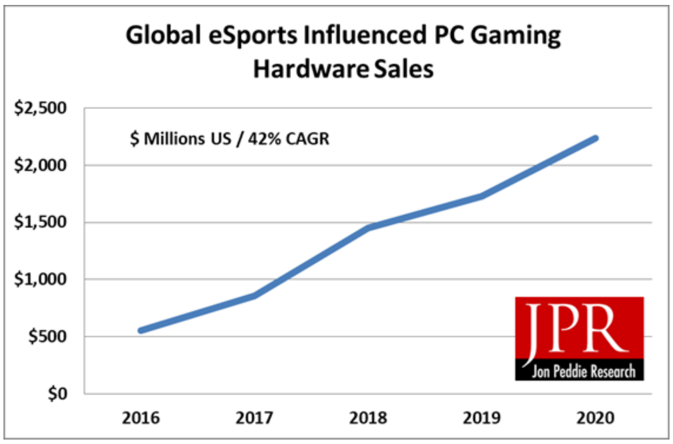
One of the most common kind of injuries in eSports affect the wrist, and it can be threatening to the performance and career of professional gamers. But the injuries of players can also threaten the economy of eSports since medical treatment is an expense. Currently there is no organization dealing with the health of players and teams do not have a medical staff. (Thiemo Bräutigam, 2016)

ESport and business

As eSports grew in the last years, the business and economy involved grew as well. ESports are now entering a new phase of maturity in their business: the general eSport economy is starting to be stable and continuous, and the salary of the players is soaring. According to Newzoo - the global leader in eSports, games and mobile -, the global eSport economy would grow to $905.6 million in 2018, a growth of 38% compared to 2017. 77% of the growth would be generated by sponsorships and advertising directly, and by media rights and content licenses indirectly through investments. The brands would spend $694 million in such investments: of those, $359 million would be spent on sponsorship, $161 million on media rights and content licenses and $174 million on advertising. $96 million would be spent on tickets and merchandise by consumers. The audience would reach 380 million of people.

Western Europe is the second largest region after North America with revenues of $169 million in 2018. What characterize Western Europe is the presence of localized eSport ecosystems operating in regional tournaments and leagues. The audience across countries is culturally different, therefore sponsors, media and investors operating in such local events use strategies matching the local audience. Sponsorship is still the biggest revenue stream with $62.9 million. (Jurre Pannekeet, 2018)

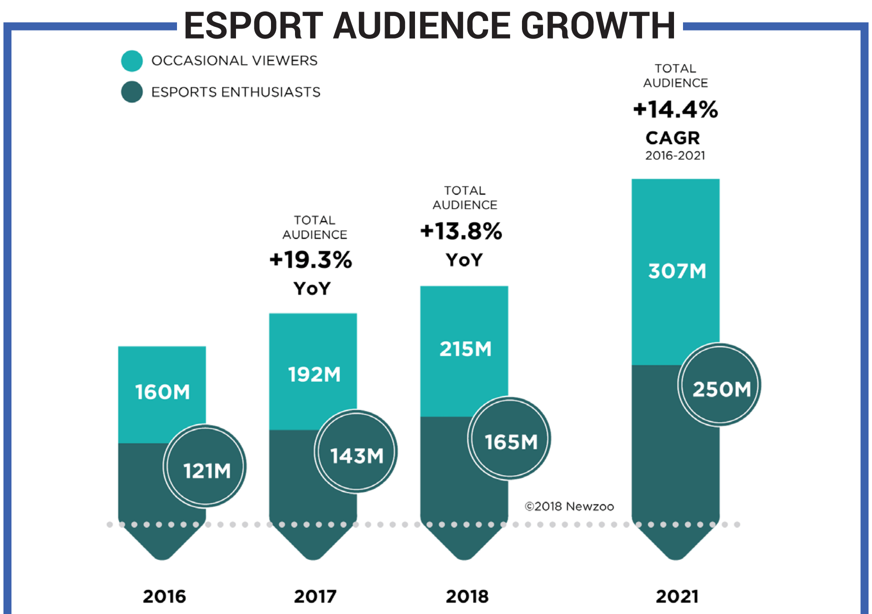
Esports influence the sales of PC gaming hardwares via team sponsorship and reachability of new customers (like new gamers). According to JPR, Gaming hardware market is estimated to reach 2.2 billion dollars annual sales by 2020. (Jon Peddie Research, 2017)



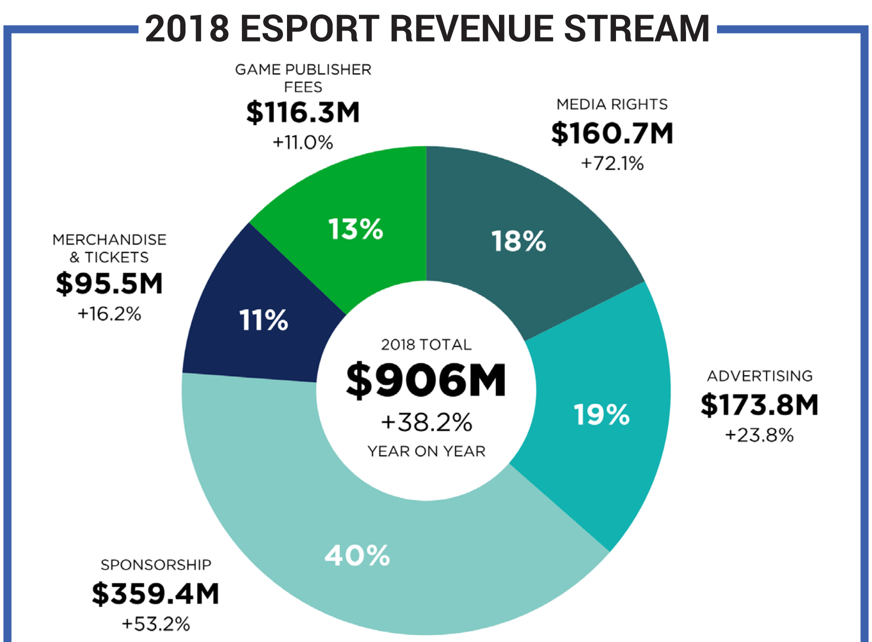
Ill. 9.1 *Influence of eSports on hardware sales (JPR, 2017)*

! Different eSports have different problems

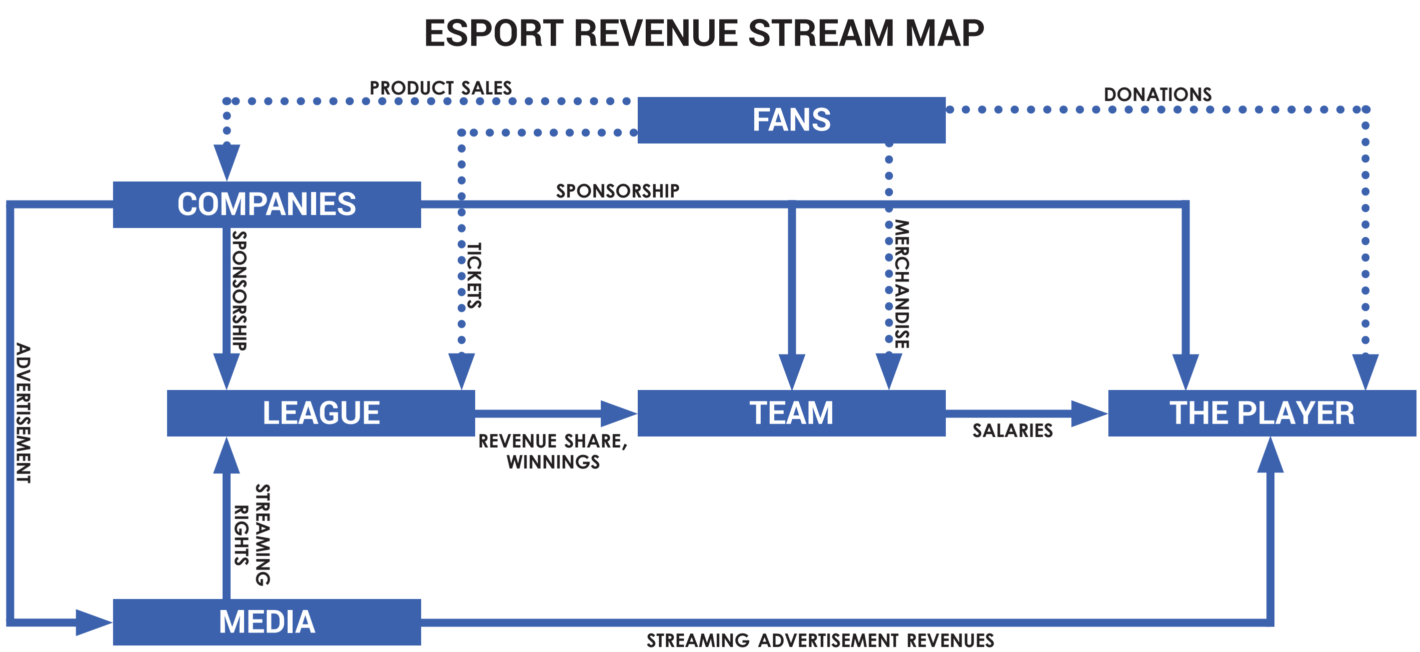
Huge market potential in eSport and hardware



Ill. 10.1 *eSport money stream (@newzoo, 2018)*



Ill. 10.2 *eSport money stream (@newzoo, 2018)*



1.2 CS:GO


Ill. 11.1

The game Counter Strike: Global Offensive (CS:GO) is used as a case study to determine the potential health hazards and problematic behaviors encountered in the eSport scene. The studies and findings will refer to this game only, but this alone might allow to recognize and acknowledge more easily the related problems found on similar games.

The significance of the game

Counter Strike: Global Offensive (CS:GO) it is currently one of the biggest eSport games, and the gameplay demands fast movements and reaction speed. The tournament ELEAGUE Major in Atlanta had 839 721 registered viewers. The Danish team Astralis won the tournament and the prize was nearly 3,5 million DKK. This victory made them the 1st ranked team in the world. (Christian W, 2017) Overall the recorded price money for 2017 was over 19 million dollars across almost 900 events. (Esportsearnings.com, 2018) The game currently has 246.790 players online, and a maximum of 715.850 players at the same time within the last 30 days. (Data recorded at noon CET time 08/02/18 on Steamcharts.com, 2018) Its longevity (the game was launched on 2012), its popularity and its important presence on the international professional eSports scene are all prime reasons for which this game was chosen as study case.

The gameplay

CS:GO is a team-based action game centered around the conflict between terrorist and counter-terrorist squads. The format used in eSport is the competitive mode that opposes two teams of 5 players each in an asymmetric gameplay. The T (terrorist) team starts on the offensive, its objective being to plant a bomb (at one of the two bomb sites present on the map), while the CT (counter-terrorist) team has to defend the sites, or defuse the bomb if that failed. Teams win by either eliminating the enemy team, by successfully detonating the bomb (for T) or by defusing the bomb (for CT). (Witkowski, 2012)

Ill. 11.2 *Explanation of the interface of the game (Valve, 2012)*

The career of eSportives

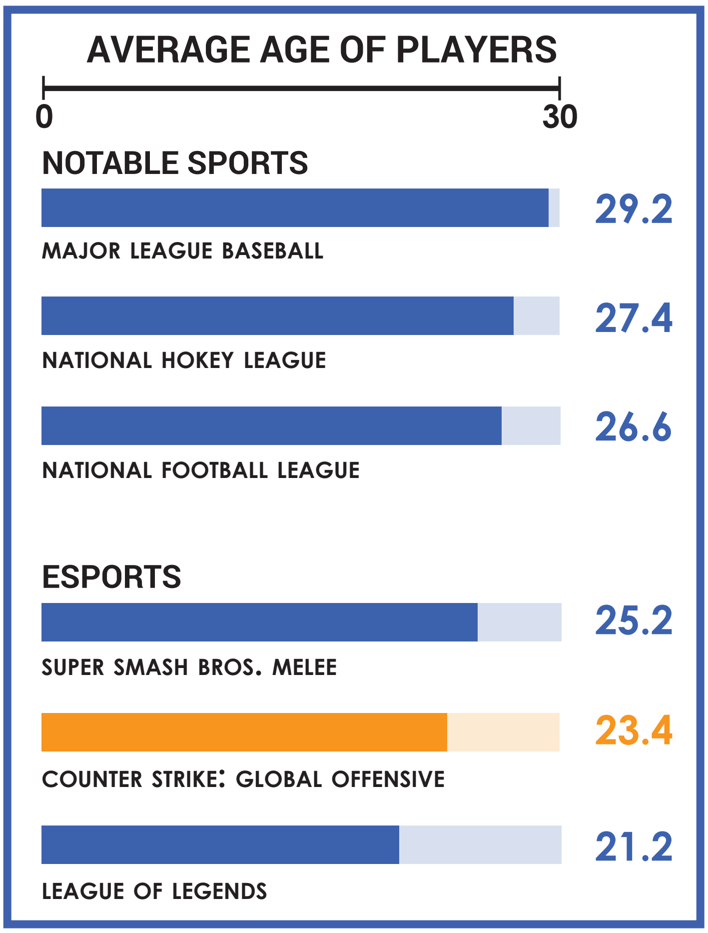
The professional career of CS:GO players usually starts around the age of 19 years old and ends around 30 years old. (Worksheet 39) Sometimes the career of a player ends in their mid-twenties, depending on the health of the athlete. (Martin Schütz, 2016)

Most of the major injuries tend to happen around mid-twenties, shortening their career even further. This depends on the severity of the injury; the recovery can take from a few months to a year, and sometimes surgery will not give complete relief. This takes a lot of time away from the peak time of their careers with recovery, rehabilitation and re-training to play the game. Thus some professional players are forced to retire. (Thiemo Bräutigam, 2016) (HLTV 2018)

At the end of their career some eSports players become commentators, coaches or otherwise try to stay in the industry like in regular sports, e.g. Danny "zonic" Sørensen became coach of the team Astralis. (HLTV 2012)

According to Lasse Kjær, a DGI eSport consultant (Worksheet 41) and Jakob Larsson (Worksheet 49), coach at Aalborg eSport, children usually start to get interested in games like CS:GO at the age of 12 (in rare cases before this age).

From this age onwards, and like in any other sport, the players usually need to train every day if they hope to become professional.



Ill. 12.1 *Comparison bewteen average age of players in sports and eSports.*

Ill. 12.2 *The average career of a CS:GO professional player. (Own illustration)*

ESport careers are short

Recovery takes time away from the game

The archetypes of players

The CS:GO players can be divided into different archetypes according to their dedication and time they spend playing the game. (Worksheet 50) This classification will help to understand the types of gamers an the differences between them.

To analyze them, Danish players are taken as a sample. The terms hardcore, midcore and casual are used in the gaming industry.

HARDCORE GAMERS

Professionals:

This is their full time job. They meet with their team and practice/work for 8-10 hours every day in the weekdays. (Worksheet 20)

Their age is around 19-30 years old (average age 23,4 years old).

Earnings: Astralis players gets a salary of 9.000-10.000 dollars per month, a travel expenses fee of 1.080 dollars per day and a percentage from merchandise sales.

Aiming to be professionals:

They train more than professionals, around 11,5-13 hours per day to become professional. Dedication to the game is needed to make it. (Worksheet 20)

Their age is typically around 12-18 years old. (Worksheet 41)

Earnings: They win prizes of tournaments at big LAN parties around Denmark, but for most of them this is not enough to make a living.

MIDCORE GAMERS

Semi-professionals:

They are the middle level players. They are dedicated to the game but do not aim to become professional. They typically have played for around 1500 hours in the game. Their daily average play time varies from 1.4 to 2 hours.

Their age is around 12-30 years old.

Earnings: Some go to LAN parties and participate in tournaments, and might earn some money by winning but far from enough to sustain themselves.

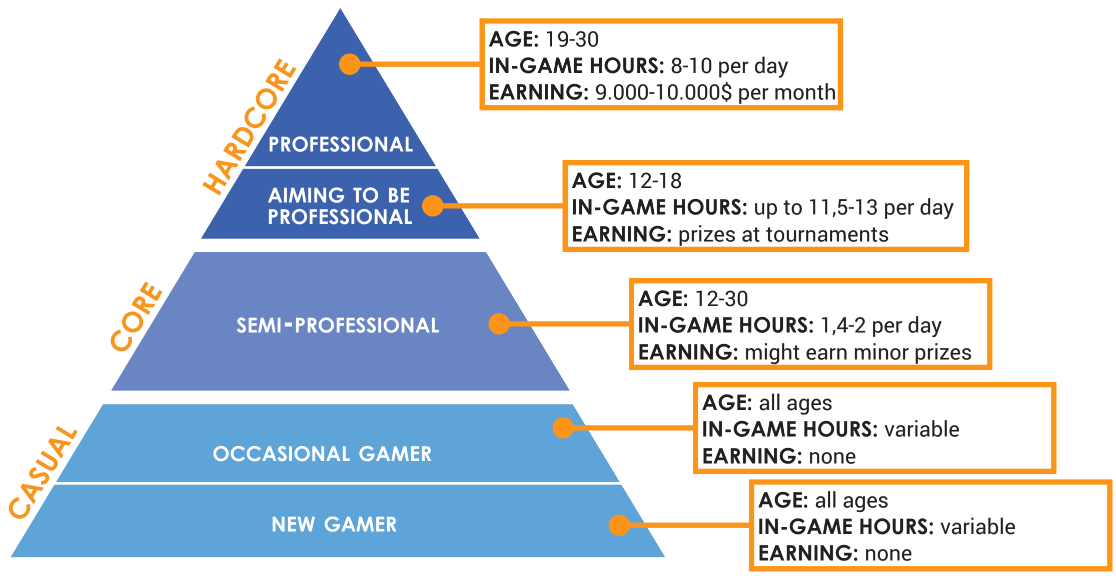
CASUAL GAMERS

Occasional gamers:

They do not dedicate much time nor effort to the game. They mostly play for fun and to pass time. They can be all ages.

New gamers:

People new to the game, can be all ages



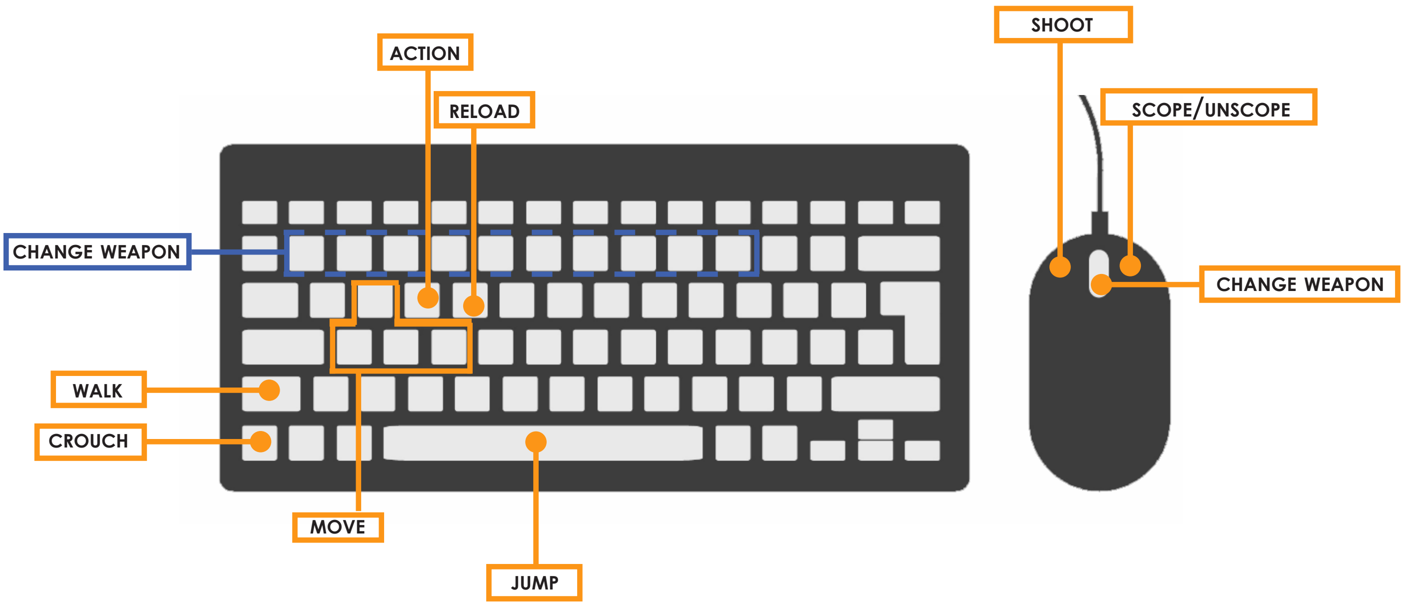
Ill. 13.1 *The three main categories of gamers: Casual, Core, Hardcore. (Own illustration)*

The game controls

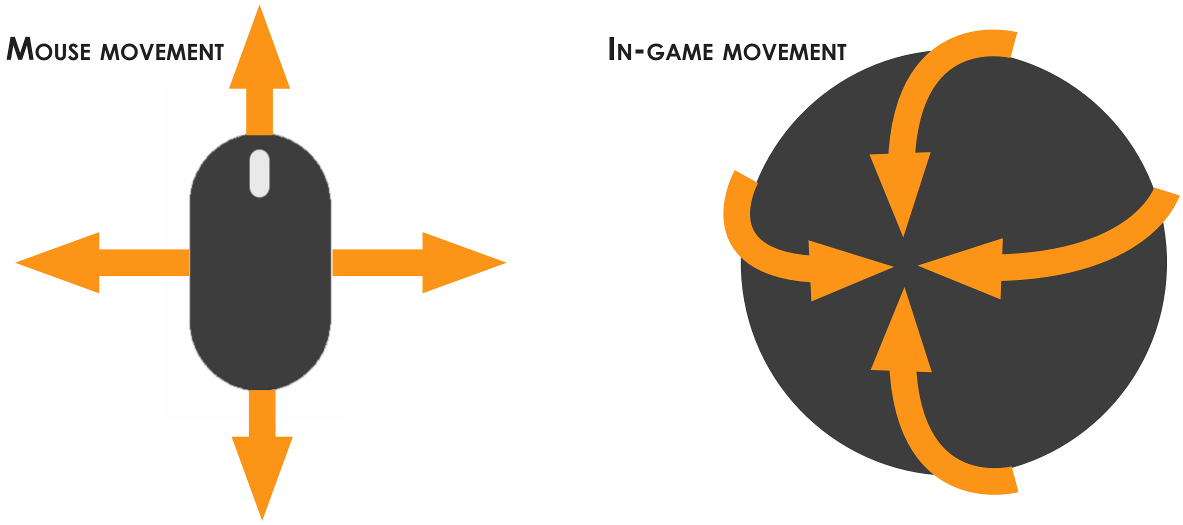
The game is usually played using a keyboard and mouse as input devices. The keyboard controls movement and the mouse controls direction and aiming. The game can be played with input devices such as joystick or xBox controller instead of a mouse, but using a mouse is faster and more precise. (Chalk, 2017)

The mouse is the main input device, and It is the hand controlling it that is the most prone to injuries. The movement of the mouse is done in 2 axis on a 2D plane. This movement is translated into a rotation in the game centered on the player controlled character (a characteristic typical of first person shooter games).

CS:GO players use the mouse more intensively than the keyboard, so it is most likely that they get injuries in the hand using the mouse. Though this does not exclude that they can get injuries in the other hand as well (this will be further explained in 1.4).



Ill. 14.1 *Key inputs for ingame actions*



Ill. 14.2 *The mouse movement in a plane is translated as an in-game rotational movement*

Most injuries in CS:GO players happen in the hand using the mouse

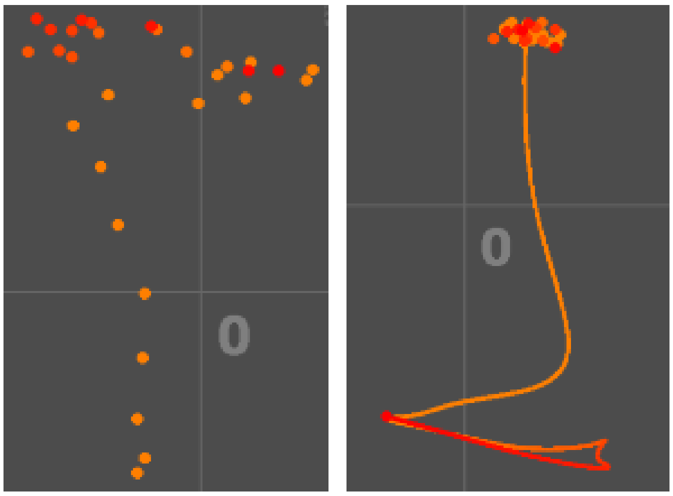
Weapon handling

When a player is shooting in the game, for most of the weapons the first bullets will hit close to the crosshair, two lines in the middle of the screen used as point of reference for the player when aiming. The more bullets are fired in close succession, the more the bullets will spread to represent real life recoil in a weapon, and favorise the players who try to be precise instead on indiscriminately shooting everywhere all the time. This is called spray pattern and each weapon has its own.

In order to compensate for the spray pattern, the first step is to pull the mouse down when firing: this will compensate for the upwards motion by most of the spray patterns. All weapons have different spray patterns making it harder to compensate for the sideways motion properly but it is not impossible. (Worksheet 18)

In the professional scene, the AWP is the most popular weapon for sniping. A professional player go from scope to unscope, move and hit precisely in less than a second. This requires to flick the wrist of the mouse hand fast.

Another aspect to what makes good CS:GO players special is how they move. Their movements need to be precise and they need to be able to turn 180° immediately in order to check behind them, spot the enemy and kill them before getting killed themselves. When moving that far in-game, their hand will also move far physically, depending on their sensitivity and other settings. In order to reset, meaning they look forward in the game and have the mouse in the middle of the mouse pad, they drag and lift the mouse until the desired position in both places have been reached.



Picture 1: shows the 'pure' spray pattern.

Picture 2: how to adjust for the recoil

Ill. 15.1 *In-game spray pattern of an AK47*

! CS:GO players need to have precise and fast movements

1.3 Injuries in CS:GO

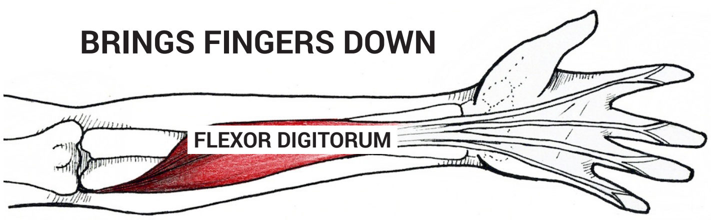
Ill. 16.1 *an eSport player with a therapeutic taping technique on his arm*

The hand structure

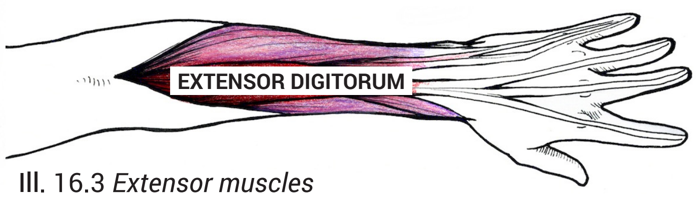
To understand why the players get injuries, it is necessary to explain the anatomy of the hand. The wrist is capable of doing a range of flexion and extension movement of 85°. The maximum ulnar deviation range (adduction) is of 45°. There are two main groups of muscles controlling the hand movements: flexor digitorum (used for example when bringing fingers down) and extensor digitorum (used for example when raising fingers up) When making powerful movements with the hand, flexor and extensor muscles of the wrist contract at the same time.

The motor functions of the hand are mostly in relation to the hand ability of gripping objects.

Every movement made with the hand involves the muscles of the shoulder because the muscles of the hand are dependent on the shoulder. (Nigel Palastanga et. al., 2006)



Ill. 16.2 *Flexor muscles*



Ill. 16.3 *Extensor muscles*

Injuries in CS:GO

Through observations made on CS:GO professional players during a game session, general scheme on typical CS:GO movements and mouse grips are delineated to understand the correlation between players's movements and injuries. (Worksheet 03)

This phenomenon can have dire consequences, as unchecked strain might lead to really severe injuries: Richard “shox” Papillon developed a cyst on his right wrist that required surgery (Jamie Villanueva, 2018); Olof “Olofmeister” Kajbjer was unable to compete on 2016 tournaments due to wrist injuries (Thiemo Bräutigam, 2016); Jacob “pyth” Mourujärvi didn’t compete for two months because of Carpal Tunnel Syndrome (Dennis Gonzales, 2016). Those cases suggest professional eSports players playing CS:GO sometimes get injuries so severe they are forced to take long leaves of absence, get operation or retire. Because of the taboo surrounding injuries in eSports and the psychological advantage it will give the other teams, it is cnsidered normal for the athletes to not talk about them. For example, in an interview Olof “Olofmeister” Kajbjer said: “I’ve heard about injuries before, but I talked to Jordan “n0thing” Gilbert and he said he didn’t want to announce it because he didn’t want people to think it was an excuse. If they played bad or something, that people might take it the wrong way". (theScore Staff, 2016) This leads the team to think that the phenomenon might be way more common than it first looks, and even though players aren't always confronted to surgery-needing injuries, strain - that has been long studied -, is the first noticeable problem.

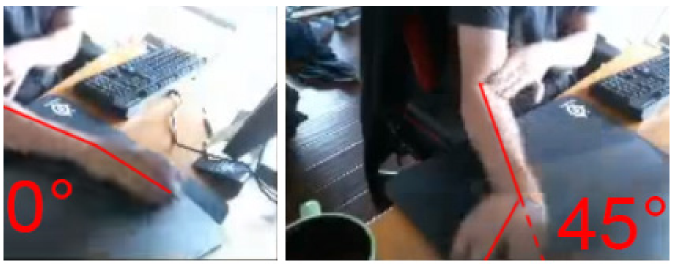
From videos showing players' performance, it was observed that the player Gabriel "FalleN" Toledo does small but fast flicks between shots with when using the AWP weapon to reset the aim between shots. Similarly, the player known as "diokotv" performs an ulnar deviation of the wrist of almost 45° while playing, and he repeats these flicks during the whole gaming session. (Worksheet 03) To perform an in-game rotation of 45° (the most frequent used rotation), the professional players move the mouse for a length of 5,6-7,8 cm. (Worksheet 28) The shoulder joint is also affected by these movements: the shoulder is capable of doing a lateral rotation of maximum 80°, and the maximum sliding velocity depends on the activity performed. Sometimes joint trauma occur due to overuse of the articulation. (Nigel Palastanga et. al., 2006)

The player Densky "LuckySkillFaker" Faker suggests that in order to get the best aim, people should use a low sensitivity and alternate between arm and wrist movement: in particular, he suggests to make wrist movement when aiming at long range (not lot of movement required) using arm movement when aiming at short range (lots of movement required) (Worksheet 03)

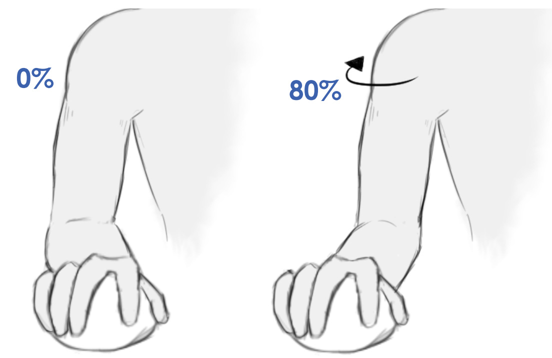
In all the observed cases, the players reach the maximum rotation in either their wrist or their shoulder. They do this fast and for several times during a day. The movements and hand/wrist positions in the pictures show the bad posture of some of the players. It is hard to see the exact angle of rotation on videos and pictures due to perspective, but by using the body of team members as reference and related anatomical theory it is possible to measure the movements. Some of the players tend to put the sensitivity of the mouse low, and in order to reset their aim (get the mouse in the middle of the mousepad and aim forward) they flick and lift their hand several times. (Worksheet 03)

It is not uncommon for professional players to experience pain from injuries related to those movements. Sometimes pain and injuries are so severe they need to take long breaks from the game or get operated. (Worksheet 03) Though, they often ignore the pain and keep playing. (Keving Wong, 2017)

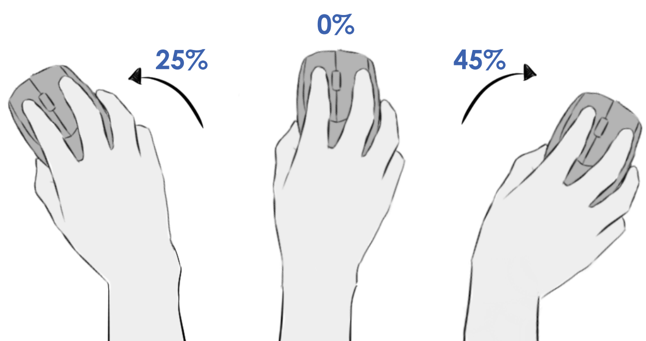
Ill. 17.1 *Adam "Friberg" Friberg: his wrist is stable, but his shoulder rotates close to its maximum*



Ill. 17.2 *Jordan "n0thing" Gilbert flicking his wrist when he plays*



Ill. 17.3 *Maximum lateral rotation of the shoulder*



Ill. 17.4 *Radial deviation, neutral position, ulnar deviation of the wrist when using the mouse*

Repetitive Strain Injuries

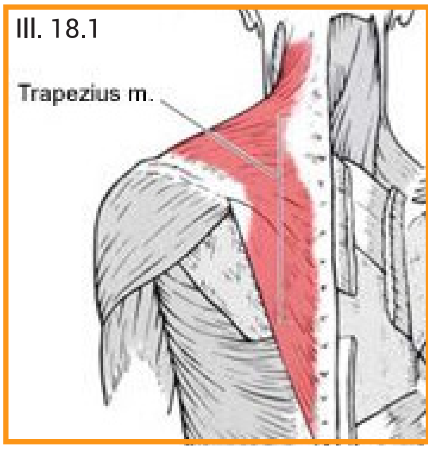
Both long use of computer and the rapid and repetitive finger movements made when using a mouse or a keyboard and posture are associated with musculoskeletal disorders. The reason behind the development of hand injuries in relation of computer use might be because of muscle fatigue due to prolonged and repetitive contractions of muscles. From the results of a test presented by Jeong Ho Kim and Peter W. Johnson, the use of mouse causes more physiological changes in the finger flexor muscles than the keyboard. (Jeong Ho Kim, Peter W. Johnson, 2014)

According to a survey conducted by Mentholatum, 21% of adults have suffered from repetitive strain injuries (RSI) (Lisa Salmon, 2016). Repetitive strain injuries term refers to disorders that develop as consequences of repetitive movements and bad postures. (Maurits van Tulder et al., 2007)

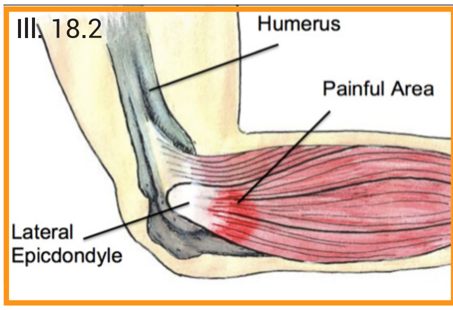
"In a survey conducted in 2016, people suffering from RSI mostly indicated feeling pain in their wrist (69%). Fingers (29%) and thumb (20%) followed as self-described pain centers." (Lisa Salmon, 2016)

The most common kinds of RSI are: carpal tunnel syndrome, mouse shoulder, tennis elbow.

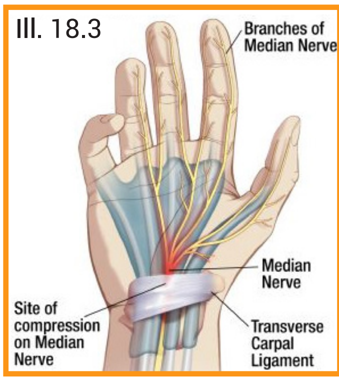
Ill. 18.1

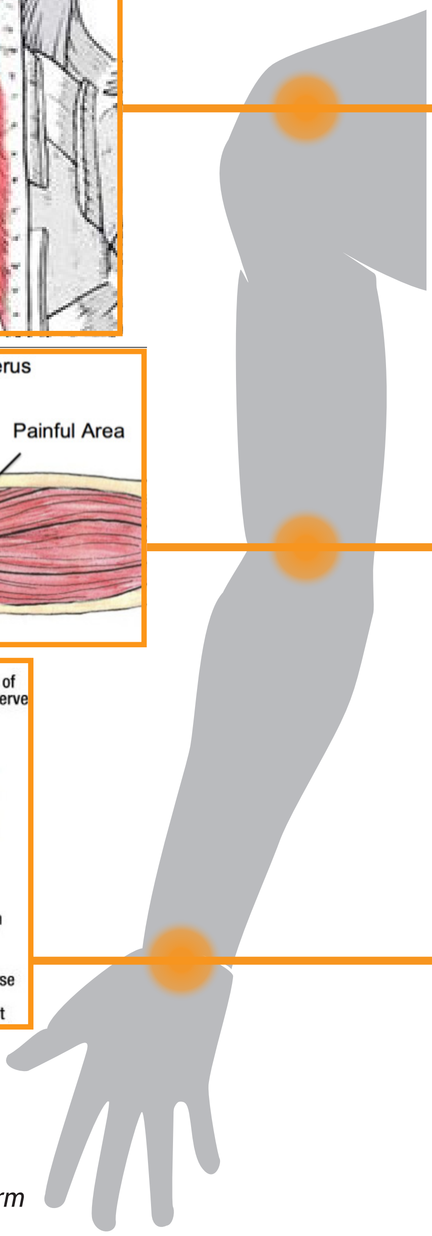


Ill. 18.2



Ill. 18.3





Ill. 18.4 *Human arm*

MOUSE SHOULDER

Using the computer for a long period of time, in particular while having a bad posture, can leads to inflammation of tendons in the shoulder joint; if the inflammation is severe, it can lead to tearing of tendons and muscles "rotator cuff ". (Merita Tiric-Campara et al., 2014)

TENNIS ELBOW

Tennis elbow is a kind of tendonitis affecting the tendons of the elbow. It is a common cause of pain. It may be aggravated by grasping and excessive finger motions. (Vic Weatherall, 2014)

CARPAL TUNNEL SYNDROME

Carpal tunnel syndrome (CTS) is the most common syndrome resulting from pressure on the central nerve in the carpal tunnel. The symptoms are hand and forearm numbness, pain, paresthesia, tingling. Around 1 out of 10 people suffer from the symptoms of CTS. (Merita Tiric-Campara et al., 2014)

Wrist is the most affected by mouse overuse

1.4 Field study

LAN parties

The team visited Breum LAN party, an event hosted by the sports union in the city of Skive, to do a first research on the perception the players have of eSport injuries and what they think is the future of eSport. A LAN party is a gathering of people dedicated to video games during which multiplayer competitions are hosted.

The players participating at this event were semi-professionals, though they gave initial insights on the psychology of eSport players.

Breum LAN party has around 200 participants and room for 360 people. They host competitions, e.g. a CS:GO tournament. Henrik Lajgaard is one of the organisers from 'Skive Idrætsforening' Skive sports union. When interviewed, he said that "eSport is the future". He understands the scale of it and that the sports unions have to adapt and integrate it. He understands the risks of getting injuries when playing, but thinks that the players do not. What brought him to host this event is that the sports union wants to open an eSports line and it will function like a regular sportsline.

The coach for Cocoon.eSports Emil "Jigsaw" Sørensen believes that eSport will be bigger than sports in 10 years. Emil Sørensen coaches a team of semi-professional players. They are all teenagers and don't think about injuries, but according to him if they see the professional players warming up their hands, they would do the same. A player normally starts playing at the age of 10. His team practices 4-5 hours a day, 4 days a week, during this time they do not take breaks and they also play at home.

During interviews with players, it is noticed that they are not afraid of getting injuries since they do not play enough to get them. Though, one admitted he could feel fatigue in his finger muscles when playing for long. (Worksheet 38)

Ill. 19.1 *Henrik Lajgaard (Facebook, 2011)*

Ill. 19.2 *Emil "Jigsaw" Sørensen (Twitter, 2018)*

Non professional players are not afraid of getting hand injuries

Professional players might influence others to use products

Ill. 19.3 *Breum LAN Party*

1.5 Current solutions

The vertical mouse, the current ergonomic alternative to the mouse, promotes a neutral wrist and forearm position to prevent or reduce Carpal Tunnel Syndrome; the idea is that this way the pressure on the wrist is reduced. Though there are no evidences of the benefits of such “ergonomic” solution. A study on the effectiveness of ergonomic mice realized on patients with CTS has shown that thepressure applied on the carpal tunnel increased when the patient use a standard computer mouse, but did not decrease with the use of an ergonomic mouse. In other words, an ergonomic mouse may prevent CTS, but can’t resorb it. (Annina B. Schmid et al., 2014)

Pen tablets too are sometimes used as an alternative to the standard mouse although their effectiveness is uknown and will be further explored.

Ill. 20.1 *Vertical mouse*

Ill. 20.2 *Pen tablet*

1.6 Stakeholders

Players might be the most visible stakeholders, but they are only one of the components of the eSport industry, and professionals get their revenues from companies, who are acting as managers. They establish their players' schedules, develop business or sponsorship opportunities and generally take care of the daily routine so the players can focus on their plays alone. Players bring the money in the organisation, and the *Management Team* takes care of financial support and funding, sponsorship, public relations. (Brandon Nolte, 2015)

There are *medical professionals* who are getting specialised in treating the injuries related to eSport. These medical professionals are specialised in injuries such as Achilles' wrist, carpal tunnel syndrome, trigger finger. This is the case of Dr Levi Harrison who treats eSport players and gives them advices on posture and hand exercises. (Emanuel Maiberg, 2015)

The *players aiming to be professionals* are at higher risk of getting injuries since they are those training for a longer period of time, but the *professional players* have a bigger influence on the market since they can potentially use the product in front of a camera during the tournaments. Some of them have a twitch or youtube channel on which they can potentially show the product, or talk about it when asked questions on socials like Reddit or Facebook. Through social media, the *professional players* can potentially influence *other players*.

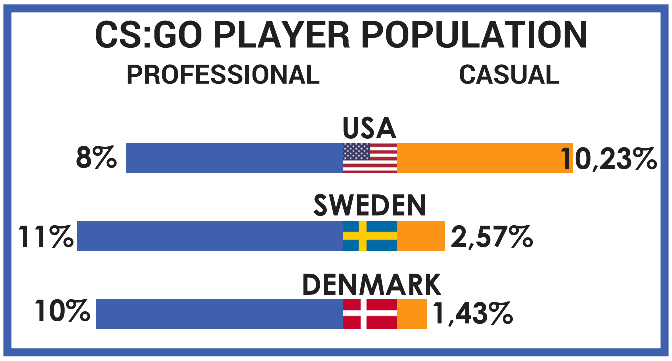
ESport in Denmark

By studying the numbers of professional and casual gamers in Denmark, it is possible to estimate the potential market the design proposal will be introduced in. CS:GO is one of the most popular eSport games in Denmark.

Denmark is the second country per earning in CS:GO with a total of $5,734,210.38 and 348 professional players. (Recording date range: 2012-2018). That makes around $16.477 annual per professional player. (ESport Earnings, 2018)

Sweden and Denmark hold 11% and 10% of global professional CS:GO players, but respectively only 2,7% and 1,43% of CS:GO casual players. In numbers, Denmark has 348 CS:GO professional players (10% of total worldwide professional players). Danish total CS:GO casual players are around 132.275. (theScore Staff, 2017)

In the last two weeks (from 22nd March 2018 to 5th April 2018) there were 553.269 active players on Steam in Denmark. 47,51% of those played CS:GO (262.858). (SteamSpy, 2018)



553.269 active players on Steam in Denmark

Professional players are the main target group

1.7 Conclusion

Although the eSport scene is growing in last years together with the numbers of eSport players, health benefits in player contracts isn't common yet. Without medical staff supervising eSport teams, players are at risk of getting injuries. This already shortened the career of some professional players.

The existing solutions to mitigate the damages are too few or not really adapted.

Given the previous points, it is hard to imagine that the answer will come from inside the industry.

Although the collected data focus on CS:GO only, the problem is extended to other eSport games.

From the initial research on the eSport scene and injuries related to the game CS:GO, initial delimitations are defined.

Delimitations

CS:GO is used as case sample, though similar issues can be found in other eSport games.

The focus is on issues of the hand holding the mouse because this is where the CS:GO players get most injuries, but it is aknowledged the overuse of keyboard can also cause injuries.

The design proposal will be designed for professional players as they can influence the market and reach other kinds of players. Though both professional and semi-professional players are met in field studies to understand players' mindset.

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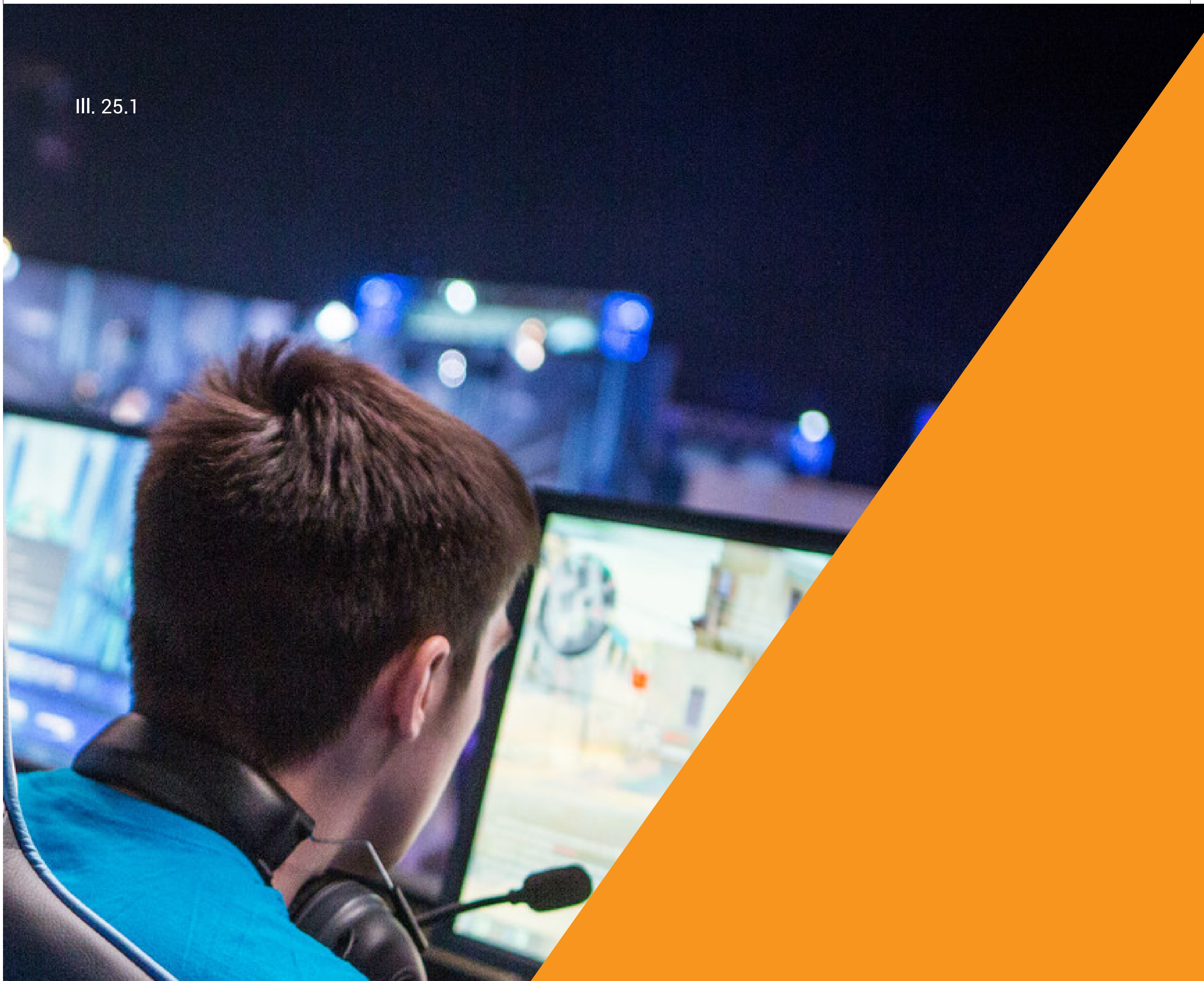


Ill. 25.1

2 DEFINE

In the following section, different solution spaces in relation to eSport injuries are explored through sketching sessions, mockups and further researches. The framework is defined accordingly and vision, mission, problem statement are determined. Delimitations are determined.

2.1 Solution spaces

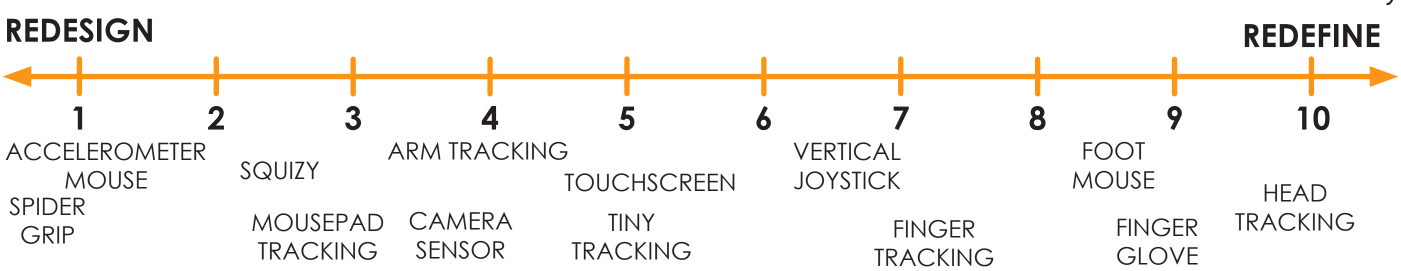
In the following chapter, different solution spaces aiming at reducing the risk of injuries in eSport professional players are explored. Each solution space is evaluated according to the findings.

Mouse research

The previous chapter helped exposing the limits of the mouse, a device that has been relatively unchanged since its inception despite its prominence of nowadays. It is therefore really important to determine where exactly on the redesign to redefine scale an action is needed: the resulting tool should be able to solve the problems causing strain and injuries, while being easy to use and reliable at the high level experienced by professional gamers. And more importantly, it should absolutely not shift the problem and create a new range of unplanned health hazards. Reducing the hand repetition movement frequency ideally reduces the risk of strain injuries. (Alwin Luttmann et al., 2003) To redesign means changing few things like shape, components and position of components; to redefine means changing the way a mouse works. This range of innovation is investigated in the first sketching session (Worksheet 22) The scale is based on the team perception.

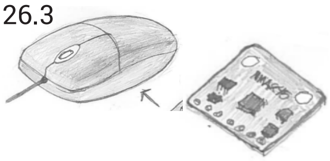
Ill. 26.1 *Mouse*

Ill.26.2 *Virtual Reality*



Selection of ideas

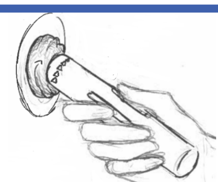
Ill. 26.3



ACCELEROMETER MOUSE

Alongside or replacing the optical sensor. Redesign of mouse sensor

Ill. 26.4



VERTICAL JOYSTICK

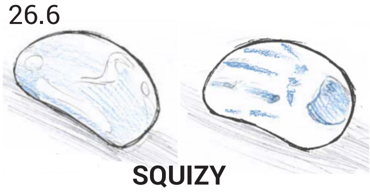
Rotates, moves up-down, has buttons. Redesign of exiting solution, redefine movement.

Ill. 26.5

FINGER GLOVE

Glove with buttons to control the game, redefine position and way of tracking.

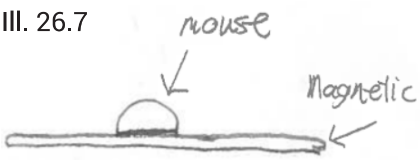
Ill. 26.6



SQUIZY

Squeeze the mouse to relieve tension, redesign of mouse materials.

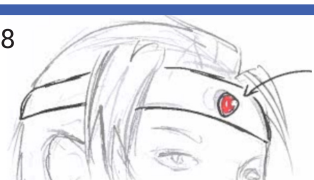
Ill. 26.7



MOUSEPAD TRACKING

Tracking from the mousepad instead of the mouse. Redesign of sensor position.

Ill. 26.8



HEAD TRACKING

Tracking using movement of the head, redefine position and way of tracking

In order to be succesful with a new product, the team have to either beat the existing products (red ocean) or bring something new to the market (blue ocean). (W. Chan Kim Renée Mauborgne, 2005)

The ideation session gives initial insights into finding alternatives mechanisms to track position and movements that need to be displayed on the screen while reducing the brutality of hand movements. Research studies are conducted on:

Accelerometers (Worksheet 23)

Camera tracking (Worksheet 24)

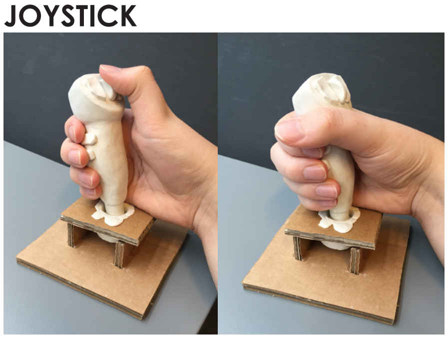
Electromagnetic motion tracking (Worksheet 31)

Information about the precision of the components is lacking in all the investigated technologies; there is nothing suggesting they are more precise than an optical sensor in motion tracking.

Alternative mouse concepts

From the initial sketching session and research into alternatives ways to track position and movements, three concepts are explored. (Worksheet 34)

JOYSTICK



Ill. 27.1 The joystick is intended to give an ergonomic grip and have the buttons placed in an easy to reach position for the thumb, index and middle finger.

PEN

Ill. 27.2 The pen is designed to keep contact with the surface when moving, so it doesn't need to be lifted. The tip of the pen is flat and have an adjustable angle to support the hand.

FOOT CONTROLLER

Ill. 27.3 The board on the left houses the buttons while the 'slipper' is used to move the mouse pointer.

Interview with John Rasmussen

John Rasmussen is a professor who works on Biomechanics at the Machine and Production department of Aalborg University. He is part of the company AnyBody Technology who develops man-machine and environment simulations.

We have contacted him in order to learn more about the biomechanical implication of different pointing device solutions, both existing solutions and initial concepts. During the interview we have presented him videos focusing on the way players position their hands and arms while in game. We also exchanged on the different concepts of controllers. (Worksheet 32)

The insights from the interview are:

- The players move excessively the wrist (both in terms of speed of movement and applied forces).

- It is important to have a good grip on the mouse. Excessive gripping can cause issues like Carpal Tunnel Syndrome. By gripping harder to become more accurate, the players strain their hands more. The surface of the mouse also affects the grip: it must be neither too rough nor too slippery.

- Doing the same movement time over time gives injuries anyway, whatever movement is that.

- The weight of the mouse is not an issue but the size is; if the mouse is too small it will increase the strain on the hand.

- Ultimately hands are built differently from person to person; this means two people may not experience the same issues when using the same device.

In relation to the concepts he said:

- Changing the surface of a mouse can give problems (eg. a soft surface like on a squizeable mouse could become sticky with moisture from the hand).

- The mouse movements do not translate well to joystick movements. The mouse records speed and position, but a joystick does not.

- When using a pen tablet there is no resting position for the hand.

- Using a touchpad is bad for the fingers as they will be extended all the time. On a mouse they are at least able to rest.

Ill. 28.1 *John Rasmussen*

Changing mouse: every repeated movement can cause RSI

! Good gripping is important, and a hard grip causes strain

Rules for eSport devices

In order to understand how much the gaming mouse can be changed/innovated, it is important to check if major tournament rules would allow alternative input devices.

In the ELEAGUE, the professional eSport League, rulebook it is stated:

"All Player equipment is subject to the approval of ELEAGUE Management and designated tournament officials. ELEAGUE reserves the right to deny the use of any equipment, **device or other facilitative object suspected of providing an unfair competitive advantage**. ELEAGUE also reserves the right to inspect all equipment." (The ELEAGUE Major, 2018)

The rule is up to interpretation, as there is no definition of what is an unfair competitive advantage. Though this means the new product is limited in its disruption and will have to compete on the parameters set by the big hardware developing companies, or the changes to the gaming mouse will have to be small enough to not be considered "providing an unfair advantage".

The idea of creating a new mouse is dismissed because:

- Every repeated movement could cause RSI, including when using a vertical mouse or a graphic tablet

- Adding more mouse movements to decrease the repetition would decrease the performance of the player

- ESport tournaments won't allow a new kind of mouse "providing an unfair advantage"

Instead of working on mouse disruption, the team decided to look at other solution spaces for the project due to the limitations set by the tournaments' rules and the high competition imposed by hardware companies.

Other solution spaces are explored, for instance to make a mouse for young players because they might not have a hand big enough to use a normal mouse. (Worksheet 40)

CS:GO mouse for children

Through field research and interviews with people at eSport organisations, it is found out that children down to the age of 12, and in some cases younger, are playing CS:GO. This can seem surprising as the game has a PEGI rate of 18, meaning it is not suitable for children under the age of 18, yet they play it regardless. (PEGI official website)

The top gaming mice comes in 3 sizes to cover most hands sizes, so no player has problems finding a mouse adapted to is hand size.. (Worksheet 41) (Worksheet 66)

Based on those facts, there is no need right now to make a mouse for children.

Ill. 29.1 *PEGI scale*

Training device for gamers

Instead of making a mouse or a mouse substitute, another solution space is explored: training the muscles of the hand in order to reduce the risk for a player to develop repetitive strain injuries."

Tournament rules might not allow a new kind of mouse

Children don't have issues when using current mice

! Training the hands of gamers

2.2 Hand exercises

Medical professionals and eSport

Recently, medical professionals have shown interest in studying injuries in eSport in eSport. This resulted in the development of a series of exercises aiming to reduce the risk of injuries. In this chapter, the exercises suggested by medical professionals working in the eSport scene are analysed.

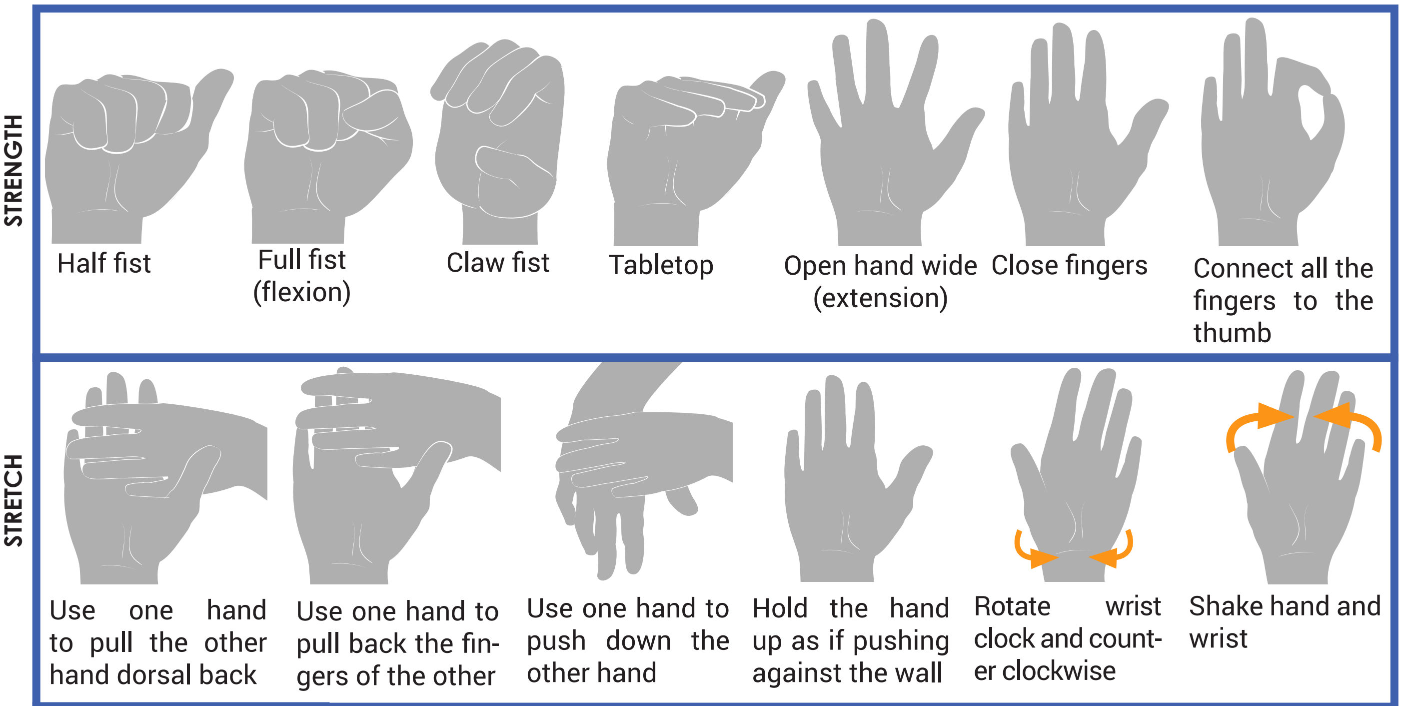
Dr Levi Harrison exercises

Dr Levi Harrison is an independent orthopedic surgeon specialised in eSport injuries. He refers to himself as the "eSport doctor". Precedently he served as Medical Director of Healthy Athletes at the Special Olympics World Games LA 2015. (Worksheet 45) To reach eSport players, he releases training videos on his Youtube channel. In an interview he stated: "It's not the same as professional treatment, but it's the kind of help that pro eSports players aren't getting anywhere else right now". (Emanuel Maiberg, 2015)

His first suggestion to players is that they take a 5 minutes break every 60 minutes of gaming and that this behavior will both improve performance and extend one's career duration by reducing the risk of developing injuries, through muscular decontraction.

Still according to him, the players should place their hands under warm water and move their fingers up and down once every few hours. Dr Harrison also developed the following exercises, which, in his words, are "essential for increasing physical performance. (Worksheet 37-45) They are divided into three categories and have different goals:

- Strength, to build up muscles
- Stretch, to extend the muscles
- Massage, to apply pressure on the muscles



Ill.30.1 *Dr Levi Harrison*

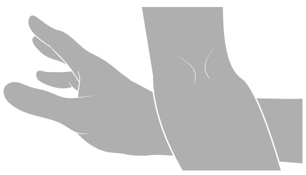
The exercises suggested by Dr Levi Harrison appear to be focused on opening and closing muscles of the fingers (flexor extensor) and stretching of the fingers, hands and wrists (monstly fingers).

The exercises are not directed to a specific type of gamer, which suggests that he tries to address all of them. Despite mentioning that these exercises will increase performance, Dr Harrison does not explain how they affect the hand muscles, and which beneficial effect they can cause.

1HP hand exercises

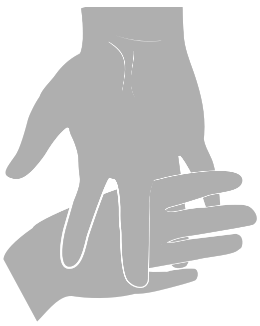
Matt Hwu is a physical therapist and strength and conditioning specialist who created 1HP, a site aiming to help gamers to improve the quality of life and gaming. He proposes a series of 5 minutes hand exercises to prevent hand injuries. Most of the exercises focuses on strecthing the hand, while he suggests one massage exercise. According to Matt Hwu, these exercises can extend the career of a professional player by two years. (Worksheet 44)

EXERCISE 1 - SELF-MASSAGE



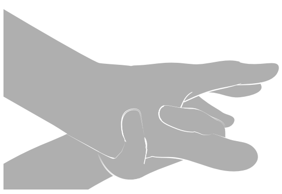
Use the elbow to massage hand, wrist and forearm.

EXERCISE 2 - EXTENSION STRETCH



Bend elbow, pull fingers and wrist back, straighten elbow and hold stretch. Add a finger with each repetition.

EXERCISE 3 - THUMB EXTENSION STRETCH



Bend elbow, pull thumb back, and down, straighten elbow and hold the stretch.

EXERCISE 4 - WRIST FLEXION STRETCH

Keep elbow straight, pull your palm until you feel the stretch along the top of your forearm. 3x5 each side.

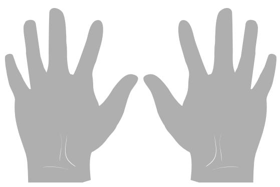
EXERCISE 5 - TENDON FLOSSING

Use one hand to spread two fingers of opposite hand apart and hold the stretch.

EXERCISE 6 - CLOSED FIST CIRCLE

Make a closed fist, roll it clock and counter-clockwise.

EXERCISE 7 - OPEN AND CLOSE



Open and close hands, tighten fist and stretch out.

Exercising hands will prolong the career by 2 years

It takes 3 to 5 minutes to do all the exercises

It is suggested to do exercises every day

Cold hands

Getting cold hands is a natural response when exposed to cold. The body redirects blood to the internal organs to protect the body. (1-HP, 2017)

When playing, gamers may get cold hands and this may affect negatively their performance. (Kari Kauranen et al., 1997)

Common causes for cold hands include sedentary lifestyle, repeated stress and smoking. (Healthy Environment, 2017) One of the ways players deal with this is by externally heating up their hands inbetween matches. Other solutions exist including doing more exercise in order to force the blood to flow back into the fingertips, and sitting better to not block the circulation in the hand. As written higher, Dr Levi Harrison proposes to do some hand exercises in warm water. (Worksheet 45) When interviewed, Dr Caitlin McGee from 1HP says she favours warming up the hands through exercise, because this solution sees its effects last the longest, by achieving the recirculation of blood in the fingertips. (Worksheet 44)

Ill. 32.1 *Player using a hand warmer*

Ill. 32.2 *Dr Harrison suggests using warm water to solve the cold hand issue*

Studies realised on the impact of stretching as a mean to prevent injuries do not suggest any influence of a warm-up in the prevention of injuries. Indeed, no significant difference in the number and importance of injuries has been reported between the tested and the control group.". (Katie Small et al., 2008) However strengthening both flexor and extensor muscles, and balancing their activity, is beneficial. (Sofia Brorsson et al., 2012) An interview with Anne-Sofie Høy, an occupational therapist in Aalborg, confirms that, by strengthening the hand with added resistance, the fine and gross motor skills are developed, and doing this will increase finger dexterity. With an increased dexterity, a player performs better. (worksheet 68) Though by strengthening the hand too much its dexterity may decrease; it would be better to have an adjustable resistance to adapt to different hand strength. (Worksheet 44)

Preventive versus curative care

Since research indicates that in the current state of knowledge, Carpal Tunnel Syndrome is an incurable chronic condition, and given the fact that it is the most common serious complication affecting gamers, the team decided to develop a preventive product in order to mitigate the risks." (Jefferson Becker et al., 2014)

▼ **The product does not need to aid in stretching**

▲ **The product will focus on stength exercises**

▲ **Adding resistance develops fine and gross motor skills**

▲ **It is important to train both extensor and flexor muscles**

2.3 Mindset of players

In absence of medical oversight in the eSport scene, it is up to the players to take care of their own health. Although some professional players are aware of hand injuries and the exercises they should do in order to avoid them, it is not common for eSport players to go to physiotherapy or do hand exercises. (Worksheet 48)

The psychology of players is investigated in order to get an understanding on how to bring them to do hand exercises.

Motivation

Motivation is sometimes described as the force guiding and energizing behavior. (Rachel B. Clancy et al., 2017) Motivated behaviors are goal-directed and guided by their consequences that satisfy present and future needs of the individual. (Richard F. Thompson, 1975) In order to understand what could possibly motivate players to do hand exercises, interviews with semi-professional players at Breum and Nordjysk LAN parties were conducted. In particular, they were asked:

- When you play videogames, is it important for you to get achievements?

- Do you set your own goals or do you follow goals set by the game?

- What motivates you to keep playing? (Worksheet 38) (Worksheet 66)

Reward and punishment

To keep performance at a good level during a prolonged period of time, there is the necessity to increase the effort of individuals, and thus increase of rewards. (Maarten A.S.Boksem et al., 2005)

Both reward and punishment systems are effective in motivating, the first by giving positive outcomes, the second by withholding negative outcomes. (Linda D. Molm, 1988) A game-like system can be used, with both rewards (game-achievements) and punishments (challenges) to motivate the players doing hand exercises. For example, in CS:GO when playing well, the player reaches higher ranks; when playing bad, player goes down to lower ranks.

In conclusion, to motivate players doing hand exercises, those need to be "gamified".

Gamification

Gamification refers to the use of game elements in contexts outside the game. Broad examples of gamification can be found in health persuasive technologies, e.g. fitness application. The typical

COLLECTED ANSWERS

"I don't look for achievements, I play for fun. I always go for winning, that's fun." - Kristoffer — **WINNING**

"I like to get achievements. I want to achieve max level. That's what keeps me playing." - Christian — **ACHIEVEMENT**

"Competition in team motivates me. It motivates you when you are lower ranked than the others." - Nikolaj — **COMPETITION**

"I always go for achievements and ranking up. We have competitions with friends to see who is the best." - Mike — **CHALLENGE** game feature used in gamification is the motivation to initiate and continue the performance. Gamified systems keep track of the activities of interest (in our case hand exercises). (Daniel Johnson et al., 2016)

In gamification, it is important to have a community of people participating in the same activity thus to allow the participants to spread informations regarding their activities. Users influence and give feedbacks each others. Sharing and exposing activities to other people seems to promote goal commitment. (Juho Hamari and Jonna Koivisto, 2013)

By gamifying hand activities according to players' mindset, it is possible to motivate them keep doing those exercises. Main challenges on this approach are: to keep the players motivated doing hand exercises even after a certain period of time, and to create a sort of community to promote said activity.

To define the level of gamification the players need to be motivated to do the exercises, a scale is used by putting samples of high and low gamified apps at each ends.

The levels of gamification are defined according to the presence of gaming mechanics:

1- Low gamification: keeping track of exercises, personal achievements, sometimes ranking system, almost or total absence of reward and achievement system

2- Fairly low: keep tracking of exercises, easy-to-get rewards and achievements, sometimes ranking system, no storytelling, choice of sharing

3- Moderate: keeping track of exercises, rewards, very low or absent storytelling, choice of sharing results, sometimes ranking system.

4- Fairly high: keeping track of exercises, moderate use of storytelling, use of avatar, choice of sharing results, sometimes ranking system.

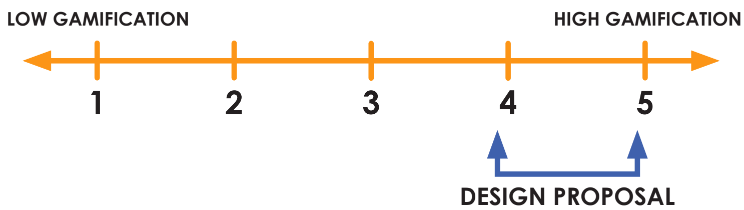
5- High gamification: use of storytelling, hard-to-get rewards and achievements, use of avatar, competition, ranking system

Fitbit is a watch that tracks the heartbeat and fitness exercises. The watch can be linked to a smartphone app that proposes different exercises and acts like a coach (frequent reminders of workout, motivational messages and an automatic selection of the difficulty of the next workout based on the user's performances). There are different levels of training. It is an example of what a low-gamification system might be.

Zombies, run! is an app that gamifies the activity of running by proposing audio stories and achievements. When running, the player collects supplies to survive the zombie apocalypse, while mission narratives and music can be heard through headphones. When chased by zombies, the player must run faster. (Worksheet 79)

Different people don't react the same to different gamification systems. In the case of CS:GO players, a high level of gamification works to keep them playing CS:GO. For this reason our design proposal will integrate farly high-high level of gamification.

Ill. 34.1 *FITBIT*



Ill. 34.2 *Zombies, run!*

Keeping track of progress and sharing as gamification

Gamification of hand exercises to motivate players

2.4 Market analysis

Existing products for hand exercises are analysed to investigate why they are not solving the problem. (Worksheet 52) Only the products aiming at strengthening the hand are considered since there are no evidence of the benefits of stretching in the prevention of injuries.

NAME	AMYCO Wrist and Strength Exerciser	Kootek Hand Grip Strengthener	Gripmaster Hand Exerciser
PICTURE	Ill. 35.1 	Ill. 35.2 	Ill. 35.3 
DESCRIPTION	Performs wrist curls with adjustable stabilizer pad	Adjustable resistance hand grip exerciser	Challenges each finger individually
USERS EVALUATION	Amazon: 4 out of 5 stars (165 customer reviews)	Amazon: 4,5 out of 5 stars (858 customer reviews)	Amazon: 4 out of 5 stars (165 customer reviews)
STRENGTHENING EXTENSORS	No	No	No
STRENGTHENING FLEXORS	Yes	Yes	Yes
PRICE	82,13 DKK	50,52 DKK	69,42 DKK

NAME	Diablo Evo Powerball	Hand Grip Strengthening Squishy Balls	Rocky Grip Hand Strengthener
PICTURE	Ill. 35.4 	Ill. 35.5 	Ill. 35.6 
DESCRIPTION	Strength training, hand exercise ball	Fidget balls to relieve stress and train hands	Reverse grip hand forearm training device
USERS EVALUATION	Amazon: 4.4 out of 5 stars (45 customer reviews)	Amazon: 5 out of 5 stars (1006 customer reviews)	Amazon: 3 out of 5 stars (79 customer reviews)
STRENGTHENING EXTENSORS	No	No	Yes
STRENGTHENING FLEXORS	Yes	Yes	No
PRICE	854,34 DKK	63,03 DKK	75,68 DKK

Evaluation of existing products

All the existing products seem to focus on strengthening either flexor or extensor muscles. None of them keep track of the exercises. The products are sold for a general public, sometimes they are addressed for athletes and musicians. The product closest to the concept is the Powerball, that is able to track the exercises. It gives an indication on how much customers are willing to pay for such a product (the new powerball costs 131,13 USD, 848.16 DKK). Though the Powerball does not train the extensor muscles of the hand and focuses on rotation movements.

The initial research led to define vision, mission and problem statement on which the design proposal will be developed around.

Vision

To make eSports a healthy sport.

Mission

To improve the health of eSport players, thus allowing them to perform at their best for a long period of time.

Problem Statement

How can the product reduce the risk of getting hand injuries and improve or maintain the performance of players to extend their career, and motivate them to do hand exercises?

Requirements

Initial product requirements are delineated from the previous research.

- The product must track, show and gamify exercises thus motivate players doing them.

- The product will focus on exercises strengthening the hands.

- The product must train both extensor and flexor muscles to create balance in hand muscles.

- The hand exercises should take less than 5 minutes so that they can be done during breaks from the game.

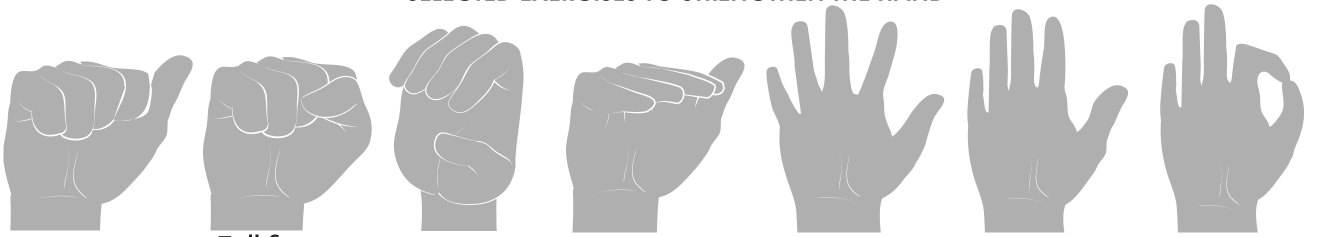
- Each digit needs to be given resistance, but the amount of resistance should be the same so to train all digitsequally. (Worksheet 68)

- The design proposal is of a tool used as a mean of prevention, and aims at reducing the risk of hand injuries.

- The design proposal will be made for both hands although only issues related to the mouse are considered in the research. This is to keep muscle balance between left and right hand muscles. Since the left and right gloves will be specular, the prototypes will be made for only one hand.

The requirements will be further elaborated when the product specifications will be delineated during the development of the design proposal.

SELECTED EXERCISES TO STRENGTHEN THE HAND



2.5 Conclusion

With the first round of sketching, the team explored the range from redesign to redefining the mouse. This also lead to further research into mouse market and opportunities. This concept was dismissed because it would have lead to a solution that would either change the repetitive movements without solving the problem of injuries, or a solution with more movements but a reduced performance.

Instead the team decided to investigate further into other spatial solutions, in particular hand exercises proposed by medical professionals to reduce the risk of hand injuries. Although some professional players know about the risk of getting injuries and the benefits of hand exercises, they do not do them because in absence of medical oversight it is up to them to take care of their health, which they do not.

According to the medical professionals, doing the exercises will increase physical performance. The strengthening exercises focuses on both opening and closing hand movements so exercise the extensor and flexor muscles. Those kinds of exercises are not specifically for a certain type of gamer, which suggest they address all gamers.

Medical professionals have different opinions on whether physically warming up the hands or using tools, warm hands perform faster and more precise than cold hands. In general, doing hand exercises prior to a match warm up the hand.

In order to motivate players doing hand exercises, those will be gamified through an application similar to those used for fitness.

By looking at the existing product for hand exercise, it was noticed that they either concentrate on flexor or extensor muscles. None of them seems to gamify the exercises.

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Ill. 39.1

3 IDEATE

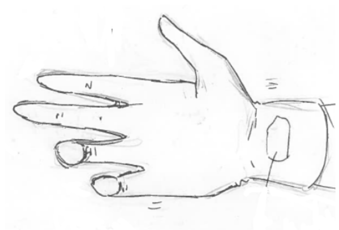
From the definition of the requirements the design proposal needs to accomplish, various opportunities are explored in the ideation phase through sketching sessions. Each idea is evaluated accordingly and the ones selected is further developed.

3.1 Sketch session

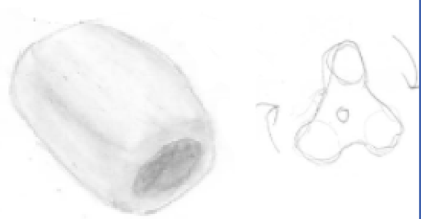
The exercises proposed by Levi and Matt, along with the cold hands, inspired a new sketching session. The objective of the sketching session is to sketch on single criteria to open up the solution space for the final concept. The sketches are divided according to their functionalities (massage, warming up, stretching, strengthening). (Worksheet **47, 55)**

MASSAGE

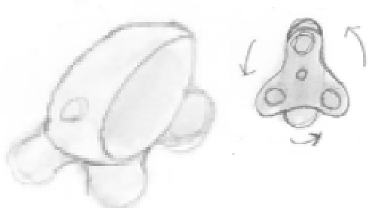
Ill. 40.1 Massage fiddle stick to increase finger agility and nobs to massage.



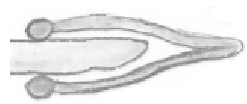
Ill. 40.2 Vibrating glove to massage and warm hand.



Ill. 40.3 Massage gauntlet device with rotating balls.



Ill. 40.4 Tiny hand massage device with rotating massage knobs.

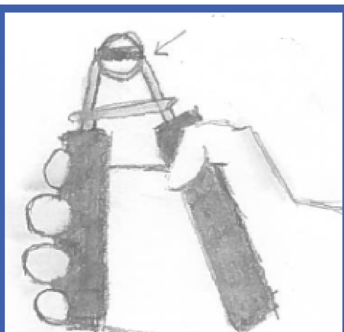


Ill. 40.5 Massage the fingers by using a stick with rollers at the end.

Ill. 40.6 Handheld massage tool with vibrating massage knobs.

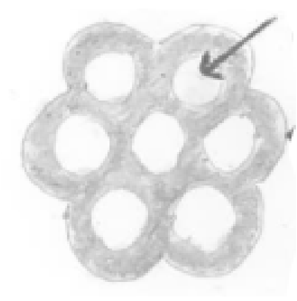
STRENGTHENING FINGERS AND HAND (FLEXORS AND EXTENSORS)

Ill. 40.7 Points registering connection with fingers when doing exercises.



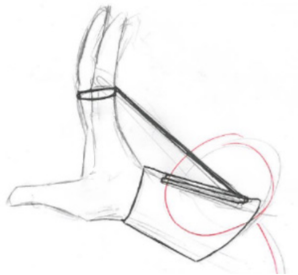
Ill. 40.8 Dial to change the resistance.

Ill. 40.9 Squize to make heat and warm the hand.

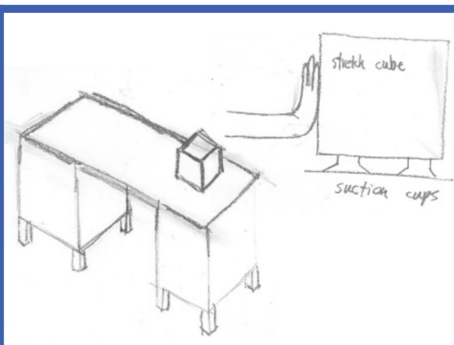


Ill. 40.10 Elastic with holes to help training the hand when opening it.

STRETCHING WRIST + HAND + FINGERS



Ill. 41.1 Wristband with spring or elastic resistance band connected to the fingers. Resistance in both directions and when moving the wrist.



Ill. 41.2 The stretch-cube has suction cups on the bottom to make a stationary surface for stretching the wrist.

Ill. 41.3 Squeeze ball with elastics to help both when squeezing and opening the hand.

WARMING UP THE HAND (EXTERNALLY)

Ill. 41.4 Glove with LED lights

Ill. 41.5 Squeeze ball with lights and heat, using chemical mixture.

Ill. 41.6 Battery driven heating pack

Ill. 41.7 Gas driven heating pack with burner inside

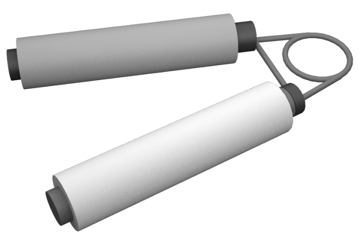
MODULAR CONCEPT

After the sketching session, the concept of making a modular design proposal that can integrate different features is investigated.

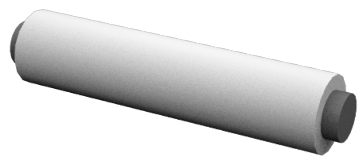
The main component is a handle with sensor components inside (Ill. 41.8).

This handle can the be attatched to different exercise equipments e.g. a hand trainer (Ill. 41.9) or a wrist curl training device (Ill. 41.10).

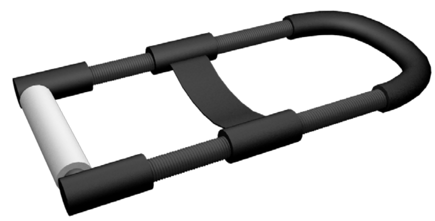
Although the concept is good in integrating different kind of exercises, it is dismissed due to its complexity. To be able to properly measure exercises, sensor in both the handle and the other parts are needed. Because of the size of such sensors and power supply, this would change the parts drasticly and also be very expensive. (Worksheet 60)



Ill. 41.8



Ill. 41.9

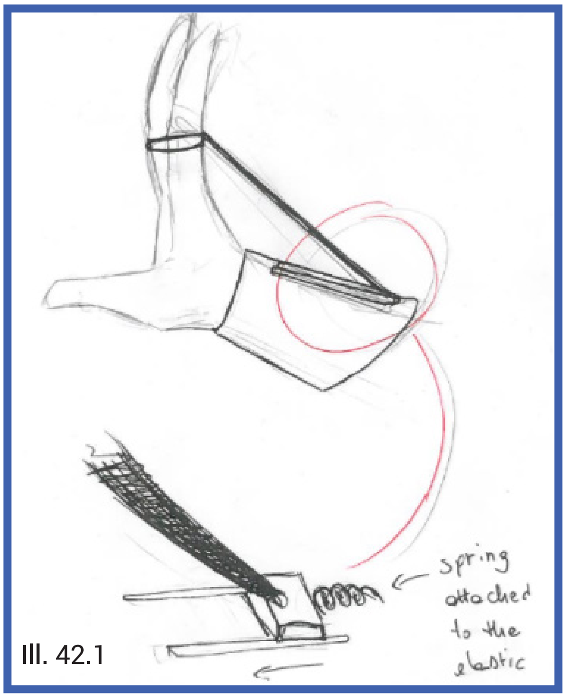


Ill. 41.10

3.2 Working principle

The gauntlet

From the sketching session, a new concept of an exercise-gauntlet is developed. (Worksheet 61)

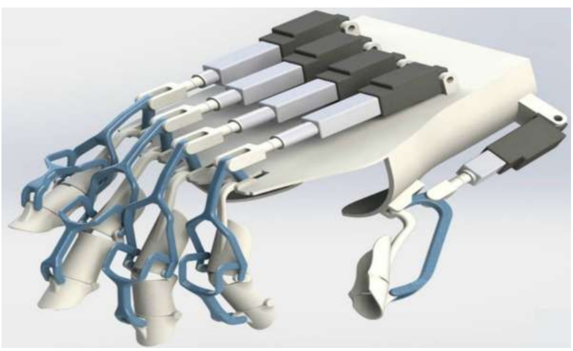


Ill. 42.1

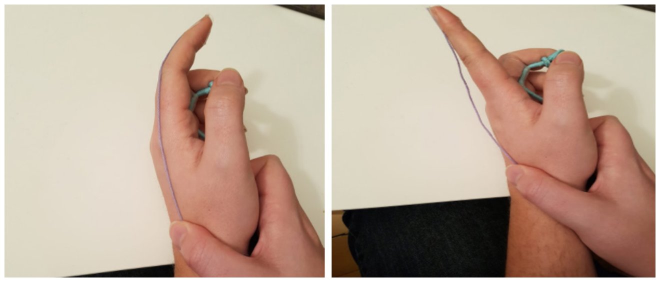
The concept is based on the sketch above (Ill. 42.1): a spring on the wrist area gives resistance to all the fingers through 3 guides on each.

The idea of incorporating a variable resistance into a glove for training the flexion and extension of the hand is then developed and tested.

The concept is selected because it fits most of the requirements: having such a resistance mechanism would allow to track the exercises while strengthening the hand. The concept gives enough freedom to perform different kinds of exercises.

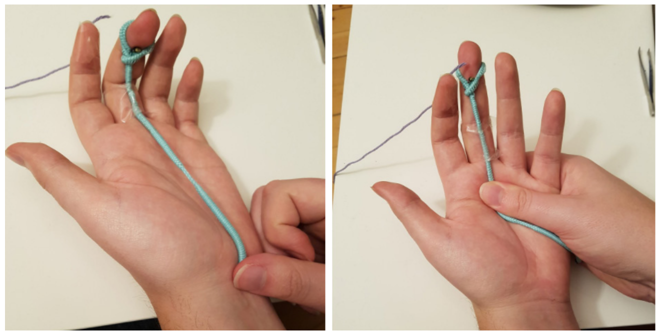


Ill.42.2 *Shells attached on top of the fingers interconnected with pistons (linear actuators) top support the hand movement to aid in rehabilitation.*



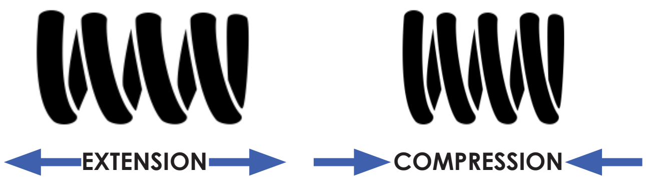
Ill. 42.3

By taping a piece of string to the index finger it is possible to measure that the length of the finger is longer when the finger is bending than when when the hand is in extension

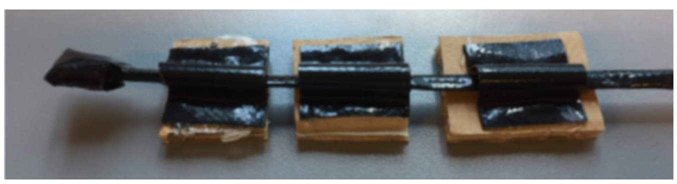


Ill. 42.4

By cutting open a hair tie and tying it to the finger, and using a second attach point on the first phalanx, it is possible to create resistance for the finger when opening the hand. This can also be done on the dorsal side of the hand instead of the palm by using a component that requires force to compress. If the component can be both expanded and compressed, then it is possible to train both flexor and extensor muscles of the hand when opening or gripping.



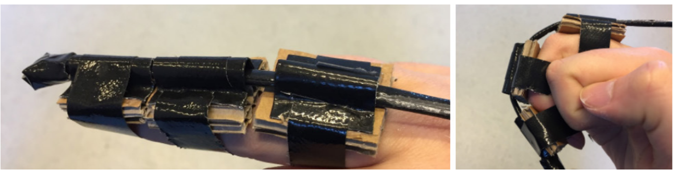
A first mock-up is made for an initial investigation on the working principle of the mechanism.



Ill. 42.5

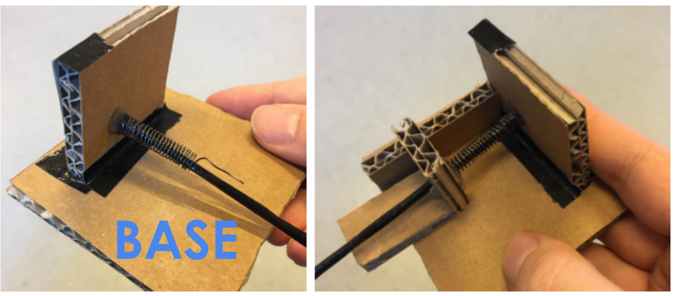
Ill. 43.1

One platform is placed on each phalanx so to keep balance in joint muscles. (Worksheet 68) To connect them, there is a need for material strong enough to push a spring, yet flexible enough to follow the bending of the finger (the rod).


Ill. 43.2

Using chalk, the top of the rod is marked to show how much it would move when the hand is closed.

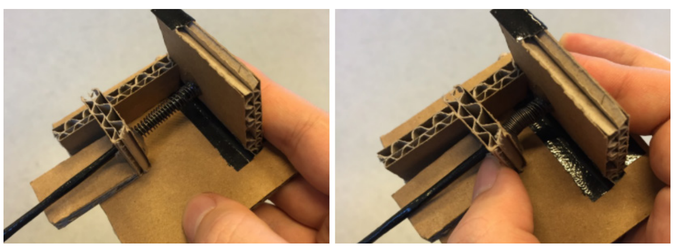
The spring mechanism that gives resistance to the fingers is then constructed. It is placed on the dorsal of the hand to not hinder the gripping movement.

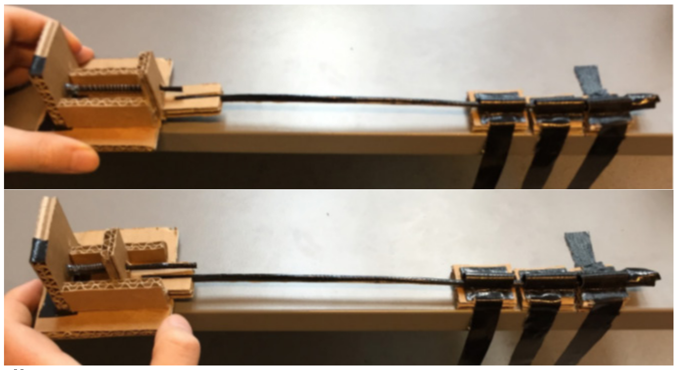


Ill. 43.3

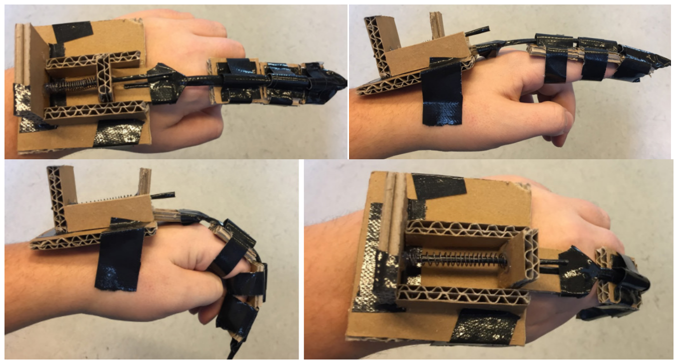
The spring is glued to a cardboard platform, the base. In order to stabilize the spring, a rod made of tape is glued to the base along with a spring.

In order to convert the push from the bendable material in the mechanism into force applied to the spring, a piston with a hole in for the rod moves through, with the spring attached to it. This makes the spring able to compress and extend while the rod is staying in position.


Ill. 43.4

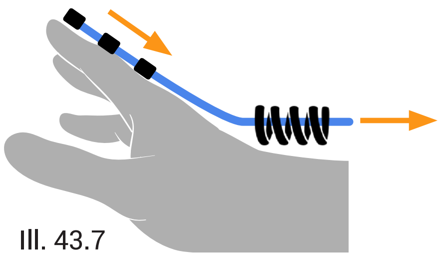

Ill. 43.5

By attaching the bendable rod to the piston, it is possible to extend and compress the spring by moving the finger.


Ill. 43.6

The mock-up is placed on the hand, the bendable rod is resized to fit, and it is attached to the three platforms and the piston. When closing the fist, the direct length, following the top of the fingers, increases. The spring expands and produces a force to go back to its equilibrium length.

When extending the fingers in the test, the force applied to the rod is transmitted to the spring even if bending: though it is required that the rod is made in a hard material.


Ill. 43.7

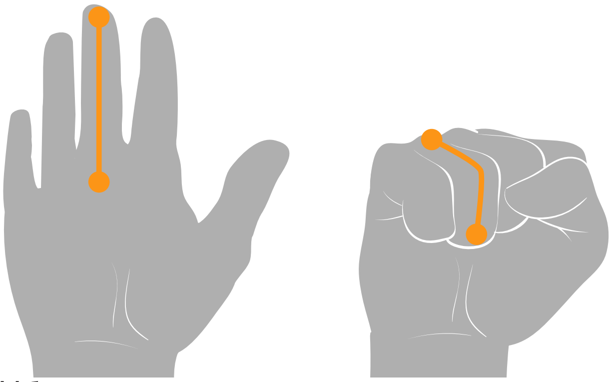
Most springs are produced to either extend or compress, which lead to further investigation on springs and the use of the same spring for compression and extension.

The base is placed on the dorsal side of the hand to ease the flexion exercise.

The resistance mechanism

Alternatives to the spring mechanism such as pneumatic or elastic systems are explored to evaluate advantages and drawbacks of those solutions. The main requirements include that they can both extend and compress, and they can fit the hand size.

In order to find out how much the system has to move, the length of the dorsal of fingers on different hand sizes is measured when the hand is extended and flexed.

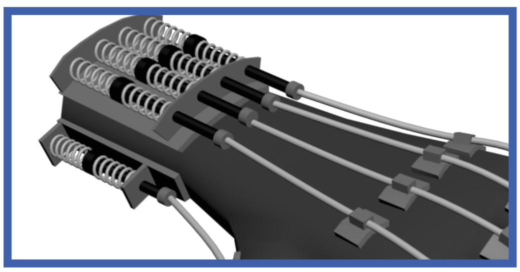


Ill. 44.1

On the measured hands, the difference of length measured on the dorsal side of the fingers in extension and flexion of the hand is around 15 mm, while in the thumb is around 10 mm. (Worksheet 61b)

Initial spring consideration

If the springs can not work in both extension and compression as shown in the mock-up, then two compression springs can be used as shown in the image.



Ill. 44.2

The image shows a mechanism with a compression spring on each side of a piston. This makes the mechanism quite big, meaning there will not be room for it on the dorsal of the hand. For this reason it is on the forearm.

It is considered that, since some hands can grip with a force of 50 kg, the solution would have to accommodate this need. The initial standing point is that this force can be divided evenly between fingers and thumb, which would mean the whole hand can pull 98 N.

The spring calculations (Worksheet 62) showed that it should not be an issue to design an affordable spring that could handle a load of 100 N and move up to 15 mm in compression. This investigation raises some questions:

- Are springs the best solution?
- How can we collect data of exercises?
- What kind of spring endings are needed?
- Can a compression spring both expand and compress?
- How important is the spring index?
- Is it necessary to move 10 kg / 98 N with each finger?

Elastic system investigation

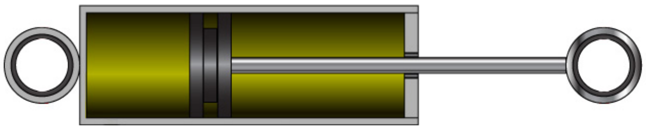
An elastic would only work in one direction, but the direction of pull could be inverted by using a pulley system. Though this system would create an issue on how to alternate between normal and inverted pulling system.

Ill. 44.3

It is also noted that some products on the market have elastics, and customers complain about them snapping.

Pneumatic or hydraulic solution

An investigation into pneumatic and hydraulic system is carried out in order to figure out if that kind of solution would fit the current product needs. (Worksheet 63)

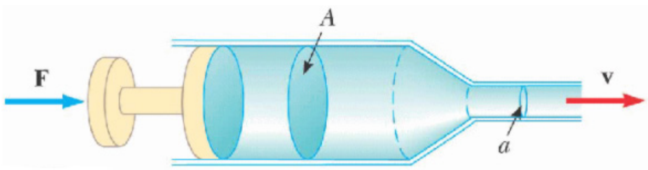


Ill. 45.1

Hydraulic and pneumatic systems have a plunger pushing into a barrel filled with fluid. The force is applied to the plunger and compresses the fluid (a gas or a liquid), or pushes it into a second barrel.

When the force inside becomes higher than the outside force, then it pushes the plunger back, decompressing the fluid to reach equilibrium of the pressure.

This principle in theory can be applied also when pushing in the other direction: the pressure inside the barrel increases and forces the plunger back to its neutral position.



Ill. 45.2

Pneumatic or hydraulic cylinders work like syringes, except they are sealed. For this reason, in order to get a better understanding of these systems, calculations and tests are made on a sealed syringe. (Worksheet 63)

When an open syringe is tested, the plunger moves easily, which means the force required to empty the syringe is quite low. By halving the speed, the required force is 4 times bigger.

Another way to affect this force is to change the size of the needle: bigger needle diameter means less force needed to push the plunger.

The force for pulling and pushing depends on speed

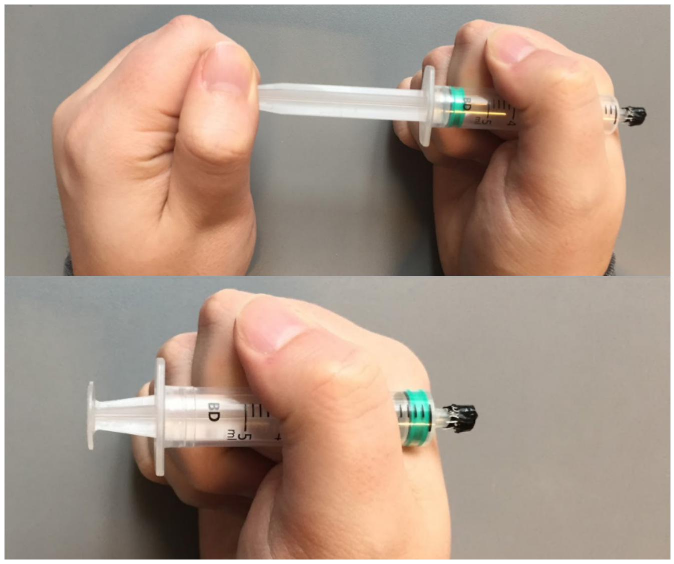
Syringe test

To test the principle, an empty syringe of 5 ml is sealed to simulate a pneumatic system. (Worksheet 64). The standard atmosphere (symbol: atm) is a unit of pressure defined as 101325 Pa (1.01325 bar) For simplifying the calculations, the air around the syringe is setted to be 1atm.

> 1atm = less room for same air quantity

< 1atm = more room for same air quantity

PULLING



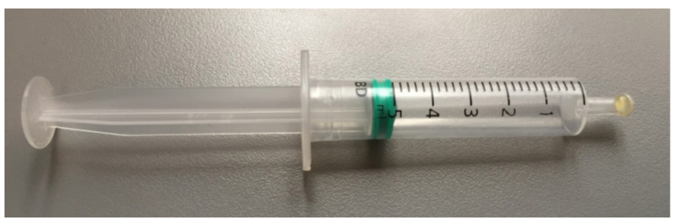
Ill. 45.3

Pulling back the plunger creates a negative pressure inside the syringe which means the outside forces are pushing on the syringe and the piston, making it hard to hold it in place. The air inside is < 1atm.

When letting go the plunger, it returns to its initial position inside the chamber (= 1atm).

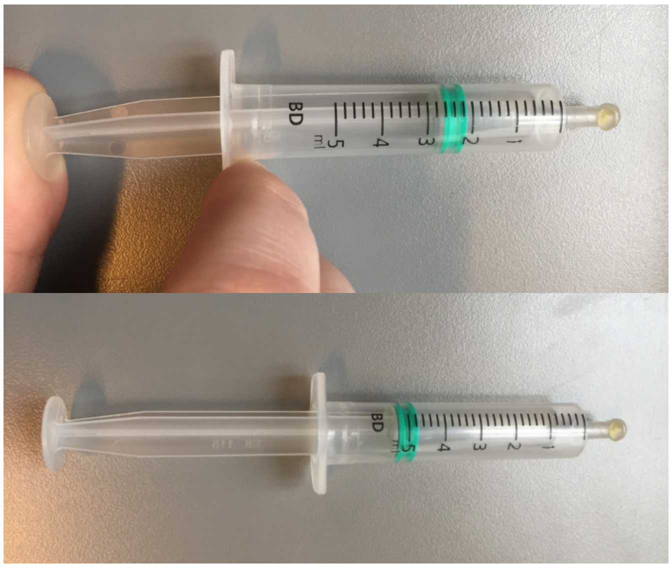
In the next test the air in the barrel is put under pressure.

PUSHING



Ill. 45.4

The syringe is sealed with glue to make it airtight.



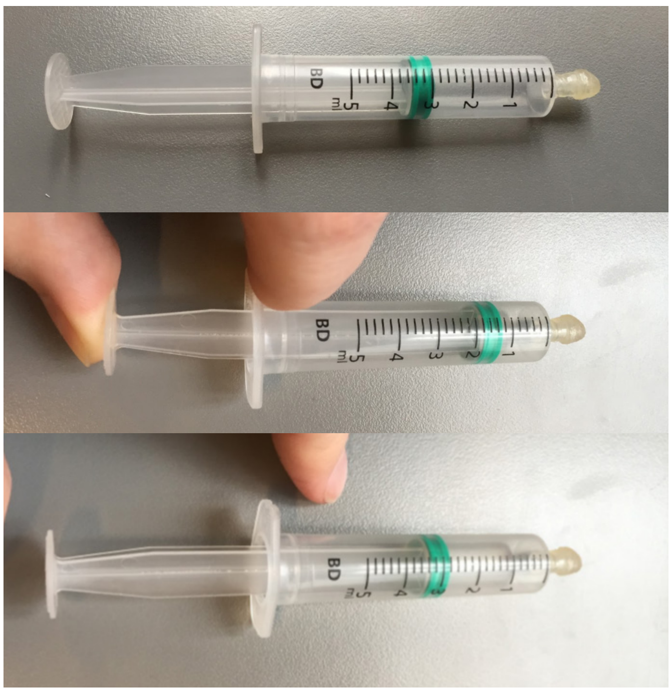
Ill. 46.1

The air is compressed to about half the volume (> 1atm).

When letting it go, the plunger snaps back (= 1atm); however the plunger does not go back to the initial position, possibly because the force needed to go back is smaller than the friction force the plunger is subjected to inside the syringe. It could also be that the piston seal not being airtight when subjected to that amount of pressure.

If the plunger initial position is in the middle of the chamber and the pressure is = 1atm, then it should be able to move in both direction when applying force and snap back to the starting position.

PUSHING



Ill. 46.2

Again the piston is not returning to the initial position. One of the main factors for the plunger not moving back to the initial point could be because when the new system is balanced, during the movement the friction turns some of the mechanical energy of the pressure into heat. (Christian Ferrari, Christian Gruber, 2010)

PULLING

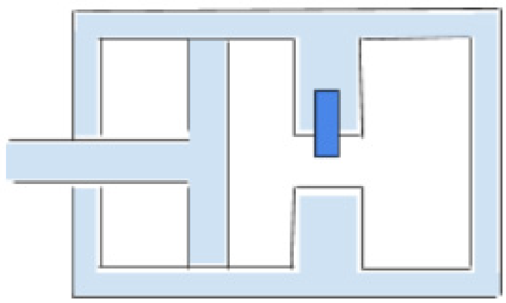
Ill. 46.3

The same goes for pulling the piston and making more room for the air (< 1atm).

The experiment shows that a closed syringe can be used to apply force in either one or two directions. With this solution the resistance depends on the pressure of the air and can not be adjusted.

As explained in the experiment, there are parameters that can make the piston not return to the initial position, the major ones being friction of the piston itself against the chamber and air passing by the plunger seal.

In this system, the force resistance could be made adjustable by having a second chamber and a gate between the two chambers to change the flow, thus the resistance.

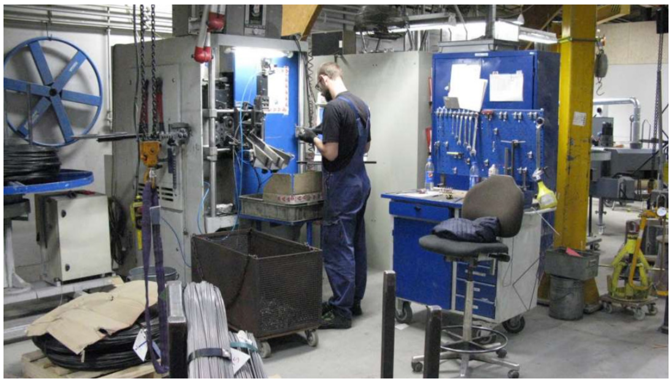


Ill. 46.4 *The dark blue box is the gate*

Visit at Hagens Spring Group

The Danish company Hagens Spring Group is contacted in order to get the questions raised in the initial spring investigation answered by experts. René Hegelund Foldager, a technical engineer working for Hagens Spring Group, is interviewed in relation to those questions. (Worksheet 70)

Ill. 47.1 *René Hegelund Foldager*



Ill. 47.2 *Hagens Spring Group factory*

During the interview, the proposed solution is discussed; it is also investigated if a compression spring can be used effectively in extension as well.

In agreement with the company, a box with 10 spring of 6 different dimentions is received.

The following insights are collected from the meeting:

- There are no issues with using a compression spring to both compress and extend; however extending the spring to a certain point can cause permanent deformation.

- Making a spring solid causes plastic deformation.

- René suggests to use a spring with closed endings to have a more stable spring; having a grinded end would make the spring even more stable, but it would double the price

- There are no issues with using either two springs as in the proposed solution or one compression spring working in both directions.

Spring test

With the springs provided by Hagens Springs, a test is prepared to verify how much force resistance is actually necessary. The strength of all digits is tested since it is a requirement that each finger should have its own resistance. (worksheet 71)

Ill. 47.3 *Preparation of the test*

SPRING DIMENSION

1. Spring: W0030713 Wire diameter: 0,8 mm Free length: 24 mm Outer diameter: 5,8 mm Total coils: 12,5	*2. Spring: W0055179* Wire diameter: 0,7 mm Free length: 13 mm Outer diameter: 8,1 mm Total coils: 9
3. Spring: W0030706 Wire diameter: 1 Free length: 47,5 mm Outer diameter: 9 mm Total coils: 12,5	*4. Spring: W0017557* Wire diameter: 1,2 mm Free length: 15 mm Outer diameter: 11,2 mm Total coils: 5
5. Spring: W0054553 Wire diameter: 0,8 mm Free length: 21 mm Outer diameter: 14,1 mm Total coils: 6	*6. Spring: W0017436* Wire diameter: 1,8 mm Free length: 25 mm Outer diameter: 14 mm Total coils: 5,4

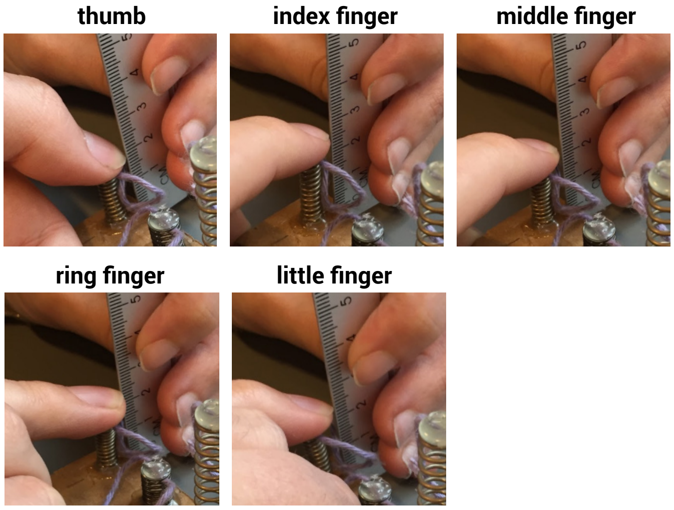
In order to test compression of the springs, they are glued to a piece of cardboard. To test their extension a piece of string is glued to the top. Some of the springs are grounded making them rough, so glue is applied to the top to make them nicer to touch.

Ill. 47.4

Two men and two women participated in the test. Beforehand one of the team members tested the set up. All participants are around 25-30 years old, around the same age of eSport players.

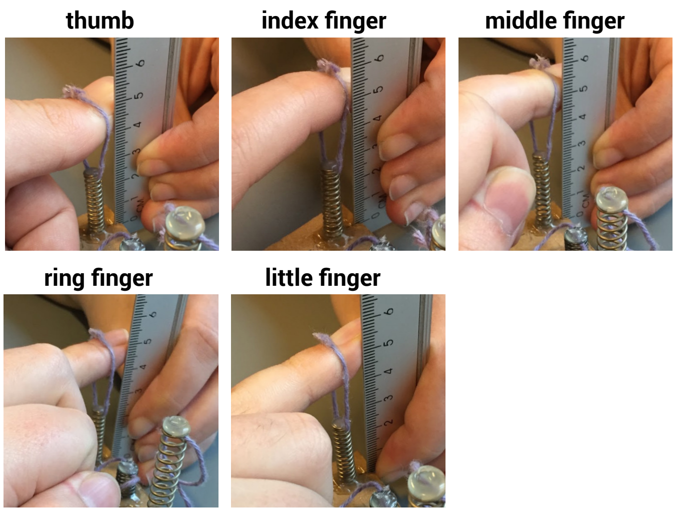
The participants are given strict instructions to place their dominant hand on the board in a resting position and only push or pull using the fingers. This allows to isolate the strength of the fingers as well as possible under the circumstances. In order to measure the length the springs move and calculate the force applied, the spring length is measured before and after applying force with the finger

COMPRESSION ON SPRING 1



Ill. 48.1

EXTENSION ON SPRING 1



Ill. 48.2

This procedure is repeated for all the fingers on all of the springs for all 5 participants. (Worksheet 71) During the test it is observed that, when extending the springs, there is a tendency of using the whole hand. In particular, it seems that Male 2 was using his hand as well as his finger to extend the spring, which could explain why in same cases he is able to extend way more than the other participants.

Maybe due to unclear instructions unclear regarding how the participants should apply the force, Male 2 bends the spring when compressing, while Male 1 compresses while holding the spring steady, which in some cases explains why he applies less force.

From the spring constant of the different springs, the displacement is translated to amount of force in Newton, and the results are compared. (Worksheet 71)

SPRING 3 - THUMB

Extension		*Compression*	
Team member	12,119 N	Team member	13,545 N
Female 1	10.693 N	**Female 1**	**22,1 N**
Female 2	16.396 N	Female 2	14.971 N
Male 1	12.119 N	Male 1	17.822 N
Male 2	**17.822 N**	Male 2	17.822 N

The above numbers are a sample of the collected data. Comparing all the data for all participants, springs and fingers, a variable resistance of 5 to 20 newton is deemed a good amount of resistance for training, considering that the players should be able to train in between matches and not exhaust their hand.

Specification: 5-20 N resistance

3.3 Conclusion

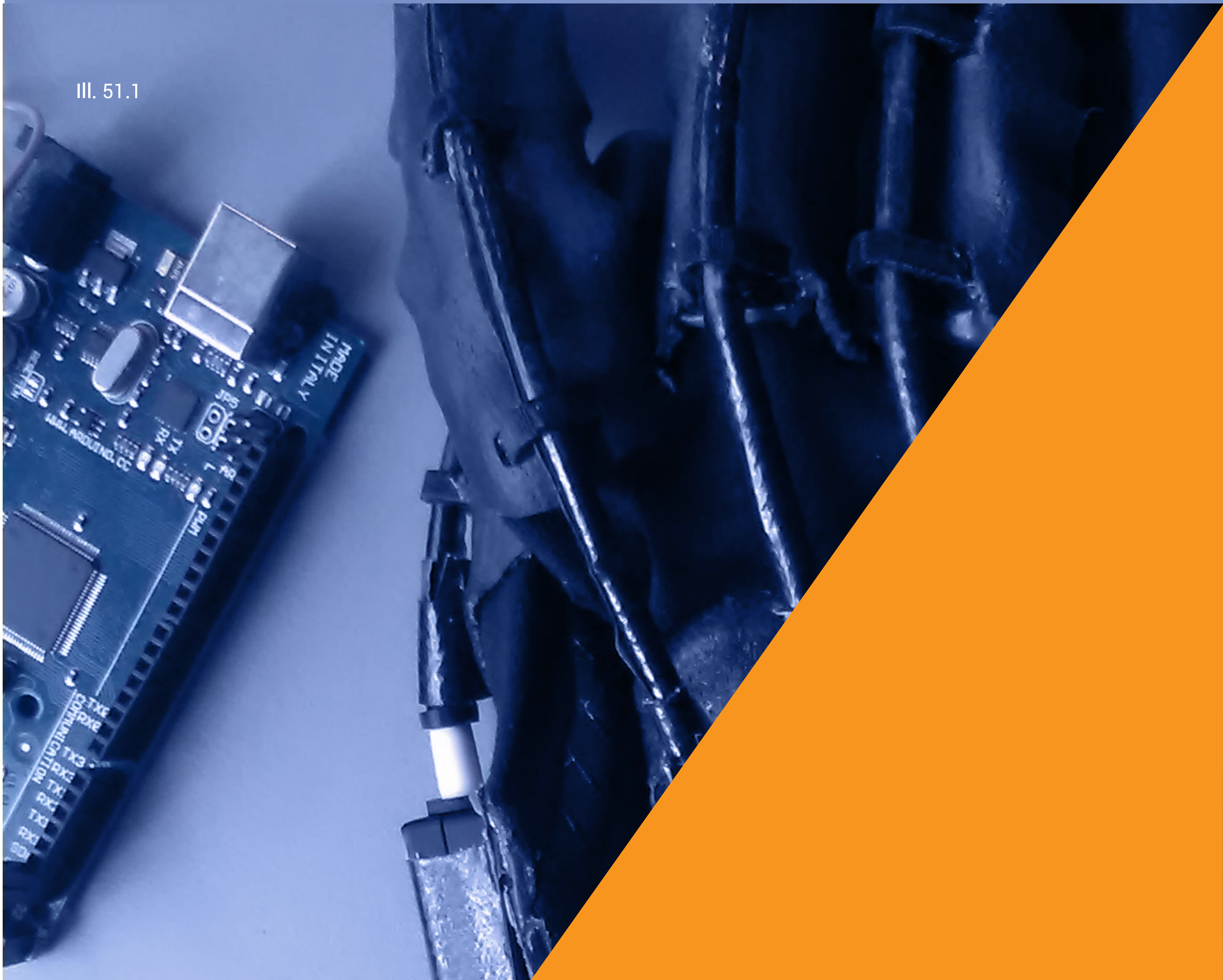
In this section some specifications for the resistance mechanism are delineated. The resistance mechanism should be able to move 15 mm and it should have a variable resistance of 5-20 N. Springs are found to be the best solution. With a compression spring being able to extend as well, it is possible to build a system small enough to fit on the top of the hand. Using elastics would require an overcomplicated system to use them in both directions, while a pneumatic-like system is not reliable n this scale and the force used is affected by the speed. Instead a spring mechanism returns to its initial position when subjected to a force and it is not dependent on the speed as the syringe.

Based on information provided by the technical engineer René Hegelund Foldager, it is decided to use springs with closed square ends.

References 3 - Ideate

Ferrari C., Gruber C., *Friction force: from mechanics to thermodynamics*, 2010, Published on European Journal of Physics,   31, Issue: 5, pp. 1159-1175

Ill. 51.1



4 DEVELOPMENT

In the following chapter, product specifications are delineated from previous research. The concept is further developed, and each part of the construction is investigated, tested and evaluated through the use of models. The objective is to construct a design proposal that fulfil the specifications and requirements. Materials and manufacturing methods are then investigated.

4.1 Specifications

Having researched into different solutions of creating resistance, met with players and explored the context, the basis for demands for the design proposal are established. The specifications here enlisted refer to the general for the product. Further on, specifications for product components will be defined. The specifications are enlisted using the method from *Ulrich & Eppinger: Product Design and Development*. (Worksheet 55)

FUNCTIONAL/INTERACTION SPECIFICATION

METRIC #	NEED #	METRIC	UNIT	MARGINAL VALUE	IDEAL VALUE
1	2	Time to exercise the hand	minutes	5	≤ 3
2	Worksheets 68, 69	Force distributed along the digit phalanges	Binary	yes	yes
3	3	Track user exercises	Binary	yes	yes
4	Worksheet 59	Work in flexion and extension	Binary	yes	yes
5	Worksheet 96	Fun to use	Subjective	3.5	5
6	Worksheet 96	Easy to put on	seconds	≤ 60	≤ 30
7	Worksheet 68	One spring resistance per digit	Binary	yes	yes

AESTHETICS/FORM SPECIFICATION

METRIC #	NEED #	METRIC	UNIT	MARGINAL VALUE	IDEAL VALUE
8	Worksheet 91	Fit different hand sizes (ø)	cm	16 - 19	15 - 20
9	3	Space for logo	Binary	yes	yes
10	12	Visible for cameras during tournaments or streamings	Binary	yes	yes
11	Worksheet 96	Visual feedbacks for actions	Binary	yes	yes

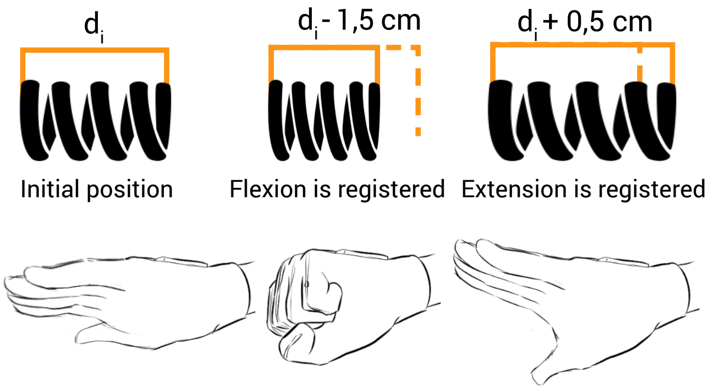
CONSTRUCTION/TECHNOLOGY SPECIFICATION

METRIC #	NEED #	METRIC	UNIT	MARGINAL VALUE	IDEAL VALUE
12	Test (Work-sheet 71)	Maximum compression spring resistance	Newton	≥ 15	≥ 20
13	Test (Work-sheet 71)	Maximum extension spring resistance	Newton	≥ 15	≥ 20
14	Test (Work-sheet 84)	Sensor accuracy	mm	± 0,7	±0,5
15	Worksheets 48, 68, 69	USB cable length	cm	70	100
16	9	Maximum weight of one glove (reference from existing hand products)	g	≤ 500	≤ 200
17	Worksheet 67	Mechanism case dimension length x width (fingers)	cm	7x5	5x5
18	Worksheet 67	Mechanism case dimension length x width (thumb)	cm	5x2	4x2

4.2 Ways of tracking

One of the success criteria for the product is to be able to track exercise progress as a part of motivating the player to keep using the device. For this reason different ways of tracking spring movements are investigated.

The sensor must register the spring movement: when the spring reaches a defined thresold in compression or extension from initial position d_i, the sensor registers that flexion or extension exercise is executed.

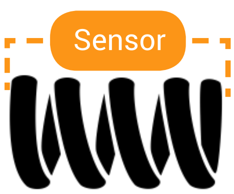


Ill. 54.1

Sensor position

Different sensors and positions are considered depending on the construction of the resistance mechanism. (Worksheet 84)

Ill. 54.2 Two sensors attached to the ends of the spring and measuring the distance between each others.



Ill. 54.2 Sensor on the side of the spring measuring the distance between the ends of the spring.

Ill. 54.4 Sensor on the side of the spring measuring the distance to the other end of the spring.

Ill. 54.5 Sensor on the spring itself measuring the distance between coils.

Some of the initial questions are:

- Is there a need for a sensor on both sides and then measure the difference?

- Can a sensor be placed on the spring and meassure the strain?

For prototyping, a sensor compatible with arduino is used as this is a microprocessor the team is familiar with. The criteria for choosing the product sensor is tied to the criteria for the spring. The spring used in the test will have a maximum free length of 7 cm and it will move up to 1,5 cm in both directions, which gives a maximum displacement of 3 cm. Ill. 54.4 is chosen because there is limited apce around the spring, but enough at one end.

Kind of sensors

Infrared: An infrared sensor consists of a light source shooting an infrared light, and a sensor receiving this light. The components can be separated or bundled together on the same board. When bundled together, the light is normally bouncing on a surface and reflected back to the receiver sensor.

Ultrasonic: Like the infrared one, this type of sensor consists of a sender and a receiver. The ultrasonic emiter fires a wave of ultrasonic sound which bounces off a surface and is reflected back to the receiver.

Optical : An optical sensor works like and infrared sensor, except it uses an optical light source.

INFRARED

Infrared Proximity Sensor - Sharp GP2Y0A21YK

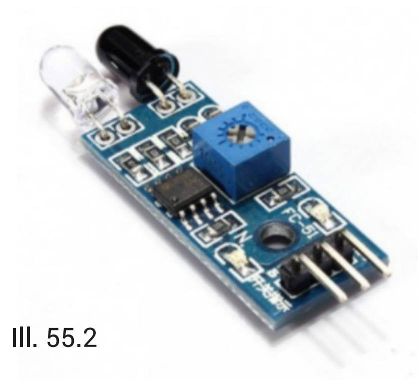
Ill. 55.1

Effective range: 40-300 mm

Accuracy: not specified

This sensor is very big and reviews revealed it is very inaccurate.

Infrared Obstacle Avoidance Sensor



Ill. 55.2

Effective range: 20-300 mm

Accuracy: not specified

The effective range of this sensor is better than the other infrared sensor.

Broadcom APDS 9960 digital rgb

Ill. 55.3

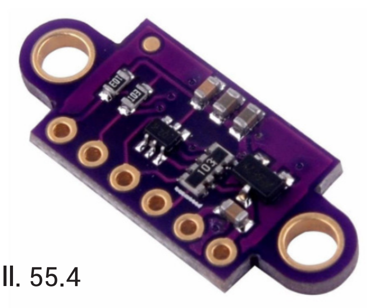
Effective range: up to 100 mm

Accuracy: ±3%

The small dimension of 3.94 x 2.36 x 1.35mm makes it perfect for small spaces.

OPTICAL

VL53L0X Time-of-Flight Distance Sensor Breakout



Ill. 55.4

Effective range: 30-200 mm

Accuracy: ±6%

This sensor is much smaller than ultrasonic but have the same accuracy.

VL6180X Time-of-Flight Distance

Ill. 55.5

Effective range: 5-100 mm

Accuracy: ±10%

Like the VL53L0X, except this sensor is made for smaller distances.

ULTRASONIC

Ultrasonic Sensor - HC-SR04

Ill. 55.6

Effective range: 20-400 mm

Accuracy: ±4%

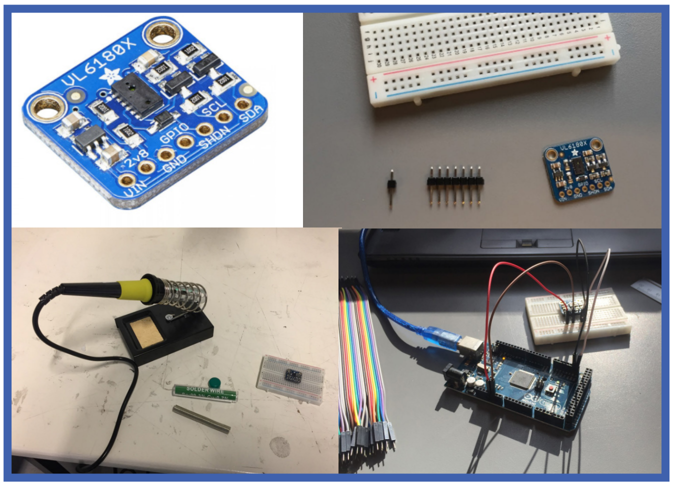
Reviews revealed this sensor to be very accurate, however it is quite large.

Chosen testing sensor

The *VL6180X* sensor is chosen for testing as a proxy sensor for the product because it can be programmed by using Arduino program, to which the team is familiar with. The sensor has a tiny laser light and a receiver. Since it uses a very narrow light source, it is good for determining the distance of only the surface directly in front of it. Unlike sonars that bounce ultrasonic waves, the ‘cone’ of sensing is very narrow. Because of its size, it can not be used for the final product.

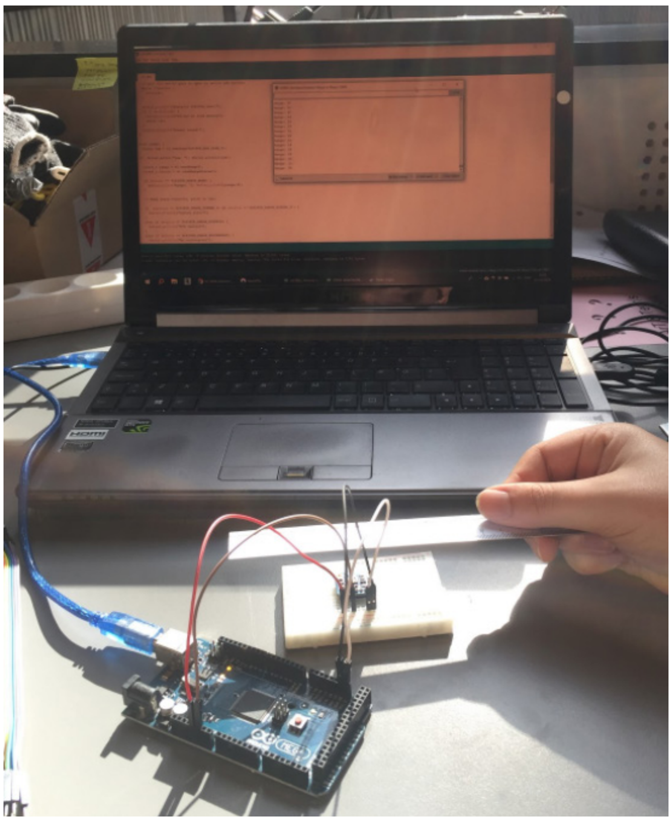
Sensor testing

The VL6180X sensor is used for testing as a proxy sensor for the product. The test aims to determine how accurate the sensor needs to be to calculate a spring displacement in such a small space. (Worksheet 83)



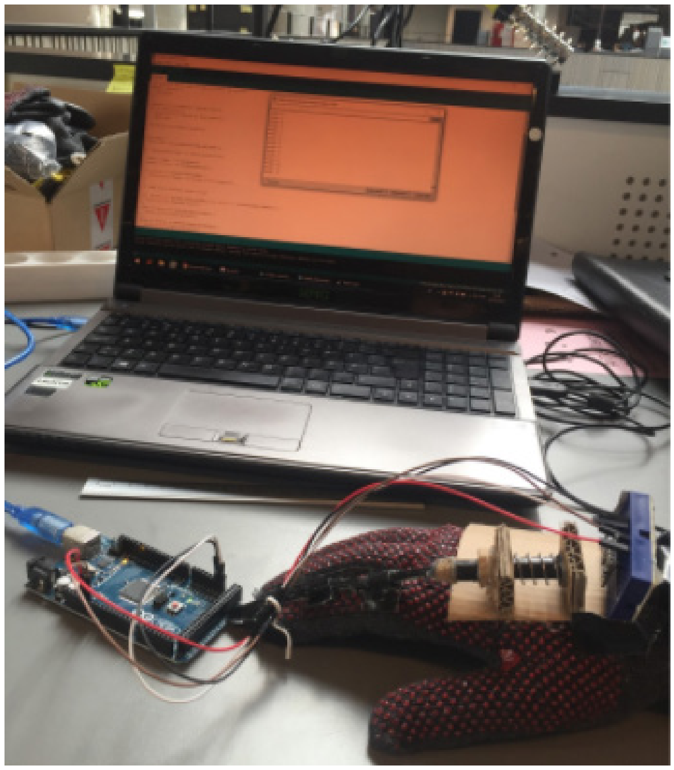
Ill. 56.1

The sensor is soldered onto pins and placed on a breadboard. The sensor is then wired up to an Arduino.



Ill. 56.2

In the Arduino program, the library for the sensor is imported as well as a basic code sample to measure the distance of a surface from the sensor. The code sample is calibrate to give the right distance between the sensor and the surface.



Ill. 56.3

For initial testing the sensor is moved to a smaller breadboard which is attached to the mock up.

On the gauntlet, the sensor measured the right distance, even with a surface in front of it not being completely straight when compressing or expanding the spring.

Conclusion

The investigation proves that a sensor with an accuracy of ±10% is precise enough to get data on a small movement such as the one in the mechanism.

With the test sensor being too big another sensor is needed for the product.

Broadcom APDS 9960 is the infrared sensor chosen to be used in the final product due to its small size and low price ($0.843 per piece if 1000 pieces are ordered). Its accuracy is ±3%, meaning that with a maximum and minimum distance between sensor and spring of correspondingly 1 and 16 mm:

d_{min} = 1 [mm]

d_{max} = 16 [mm]

Calculated Accuracy [0,3 ; 0,48] mm

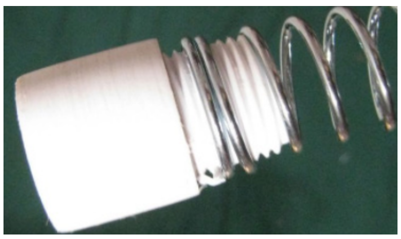
Specification:
Sensor Accuracy [0,3 ; 0,48] mm

4.3 Prototyping

To test the spring mechanism, a 3D printed prototype is prepared to find possible issues in the construction. In particular, it is investigated how to adjust the spring resistance. By 3D printing the mechanism, it is possible to get close enough to the final product to evaluate those issues.

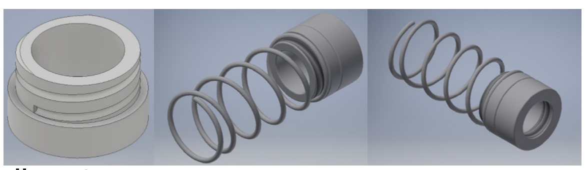
Fastening of the springs

The first issue is about how to fasten the spring to the piston. Compression springs can not have hooks like extension springs which makes it difficult to fasten them. (Worksheet 70) Normally the compression springs are placed in a cavity so they can not move out of it. With the intended functionality, this type of solution can not hold springs as when extended, they would be pulled out of the cavity. (Worksheet 70)



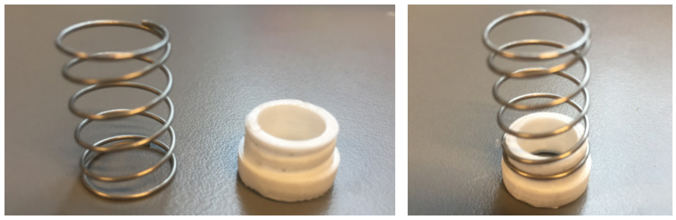
Ill. 57.1 *Attachment piece*

It is then tested a threaded attach point like the component showed above (Ill.m57.1). This would allow to change the spring length without affecting the rest of the product. For manufacturing reasons, it is better to have this piece separated from the case where the mechanism is located.



Ill. 57.2

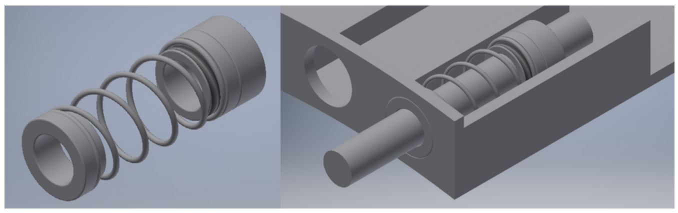
For the spring resistance to be variable, the spring length needs to be changeable. By putting threads on the inside of a dial and on the piston, the dial can move on the piston. The dial and the spring attachment piece are connected with a ball bearing making the spring able to be still while the dial is turned.



Ill 57.3

The thread is made as a circle with the spring wire diameter cutting half way into the piece. The part with the threads has the same mean diameter as the spring, making them fitting perfectly.

By making the threaded piece and the spring with the same diameter, and by making the threads twice as deep, the spring would be fastened better. This also mean that the threaded piece can be made shorter, which would allow to use more working spring coils.



Ill. 57.4

The spring mechanism is attached to the case through a threaded insert to fasten the spring to.

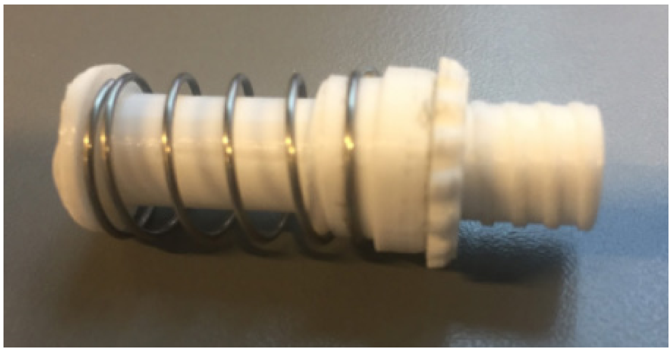
The mechanism with the threads holding the spring is very small and can be an issue when manufactured: production methods need to be investigated, otherwise the mechanism must be redesigned. The current mechanism - including the sensors - requires the case to be 6 wide and 7 cm long. Having such a big case would create issues with smaller hands; the ideal case size is of a length of 5 cm. To solve this issue, the whole spring mechanism can be made changeable: the user would then change resistance by changing the whole spring mechanism. This way the case size would be reduced since there is no need of a changeable mechanism for the spring.

Tensing mechanism

In order to test if the tensing mechanism to change spring resistance works, its components are 3D printed.

Ill. 58.1

By having a part of the piston and the inner part of a dial with threads, it is possible to adjust the position of the dial without the risk of the spring force pushing it off the piston.



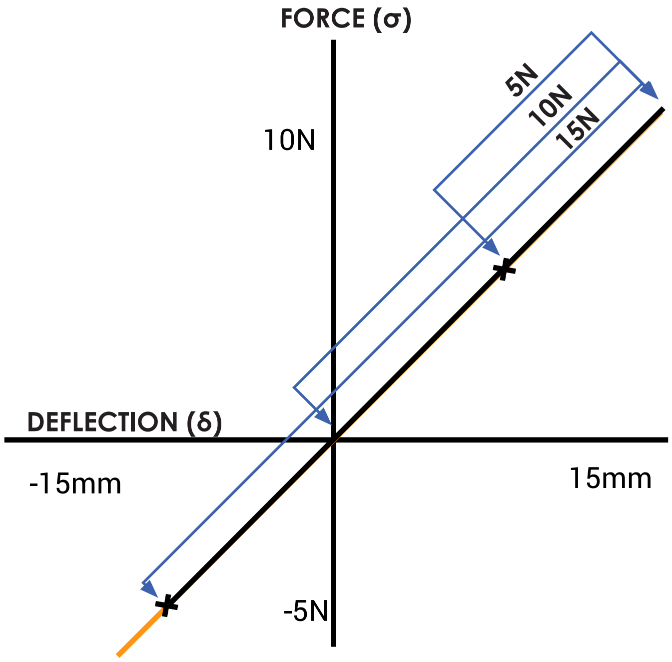
Ill. 58.2

Once the spring is attached to the dial, the mechanism is completed. Now turning the dial will push the spring attachment and pre-compress the spring. To bind the spring attachment and dial together, a ball bearing can be used.

The tensing mechanism is too big to be placed on the hand

Different spring units with 5 - 10 - 15 N of resistance will be used

The spring initially is able to move in extendion and compression for 15 mm if not constrained. This mechanism will then pre-tense the spring, meaning the finger pushing it will already be subjected to 5 N from the start and still be able to move 10 N for a total of 15 N, or reducing the force needed down to 5 N.



Different reasons lead to the team disgarding this solution in favor of a more simple and not adjustable solution.

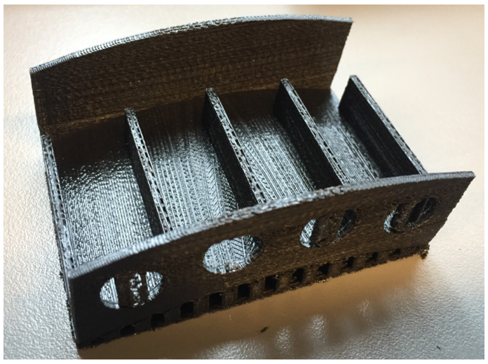
The main reason is that the mechanism would be too big for the mechanism house. Changing the size of the case containing the mechanisms would make the product fit on less hand sizes which would affect the sales.

Another reason for this solution being troublesome is the lifetime of the springs. By not changing the spring resistance, the spring is expected to have a lifetime of 10.000 cycles (133,33 days if the springs are activated 60 times a day): in the tensing mechanism, the lifespan would be reduced as the spring would be subjected to more fatigue.

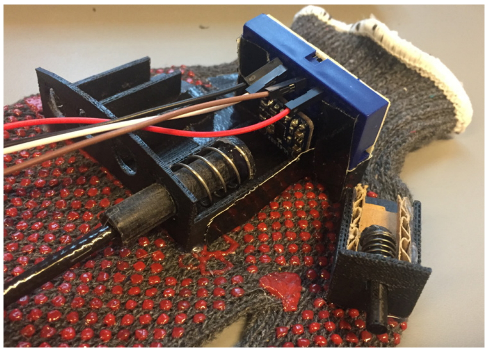
For this reason, it is decide to develop a system to change springs units each with different resistance. This would mean the mechanism would either have to be changed along with the spring or just the spring alone which would give some assembly time for the company or the user.

Developing the product

The springs and the spring attachment are designed and the general working principle is tested by 3D print. (Worksheet 88, 89)



Ill. 59.1 *The mechanism case*

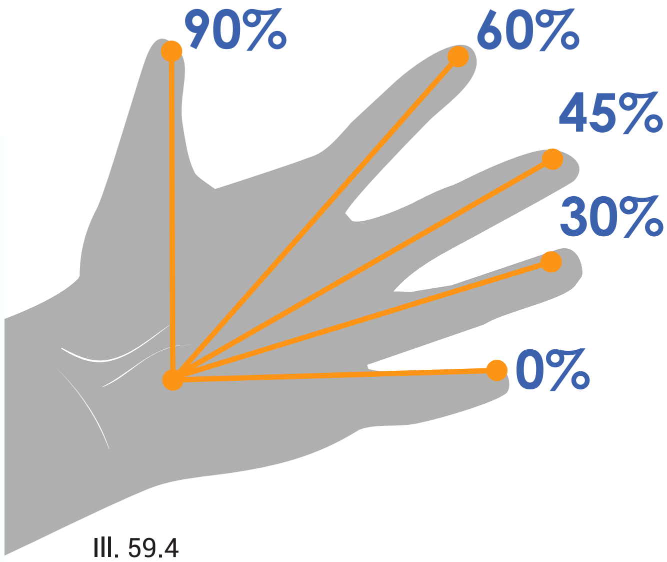


Ill. 59.2 *Prototype with infrared sensor*

The case is dimensioned according to the springs avaliable able to travel the desired length. For the thumb there is only a need for 10 mm of deflection space, which means another spring could be used in the test. The thumb case is too big for the spring available, so cardboard is glued on for the piston to travel well.

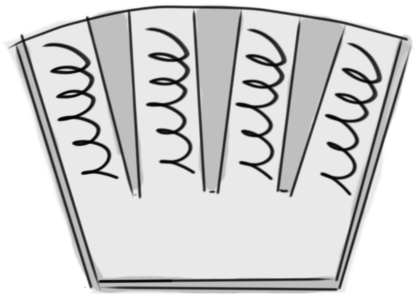
Ill. 59.3

Applying the newly printed case to the back of the glove highlighted another potential issue, which is the angle of the finger compared to the straight case.



Ill. 59.4

The angles between fingers are analyzed. When straightening out and spreading the fingers to their maximum, the angle between the fingers will be like on the above picture. (Kyung-Sun Lee & Myung-Chul Jung, 2014)

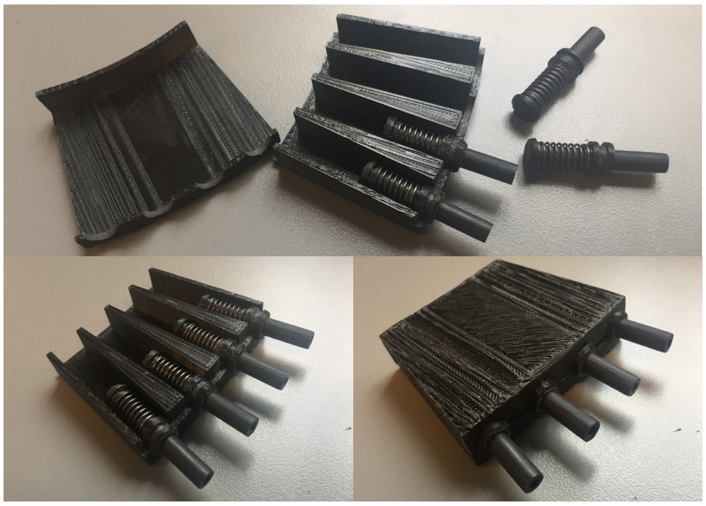


Ill. 59.5

With a quick sketch, a new angled case is designed. The needed angle between pistons will be investigated. For the mechanism to work properly, having a small angle between the fingers is better than having no angle.

Ill. 59.6

An investigation in cardboard, paper and garden gloves showed that keeping the front/top 70 mm and making the bottom 50 mm gives an indication of the needed angles between the pistons.
However this is further investigated in a 3D printed prototype.

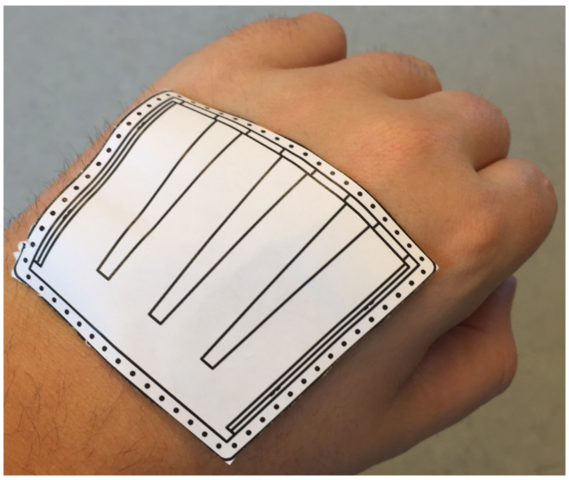


Ill. 60.1 *3D printed model with corrected angles*

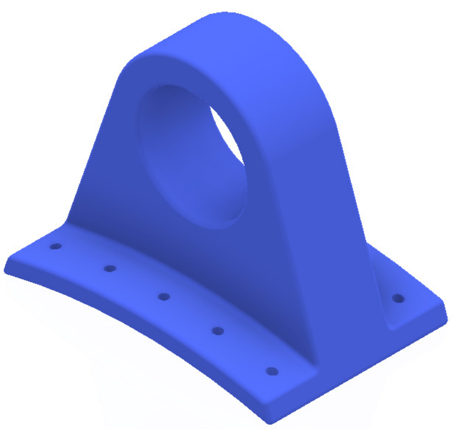
With 5° between pistons, the mechanism worked properly, meaning the movement of the fingers was transmitted to the springs.

Stitching

The case and guides will be glued and stitched between two layers of fabric. For this reason, those components have a bigger contact surface with holes for stitching.



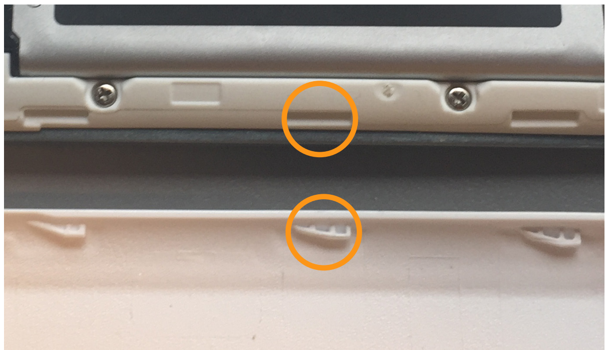
Ill. 60.2 *The size of the mechanism case with holes for stitching*



Ill. 60.3 *A guide with the holes for stitching*

Case closing system

The main mechanism case and thumb case both have lids so to change spring units. It needs to be easy to open and close, and the lids needs to be attached well enough to not fall off when the product is used. For a mechanism like this, the team investigated smartphones cases.



Ill. 60.4 *Example of click system in a Samsung lid*

Taking as example a Samsung smartphone, it is easy to put on the lid but harder to take it off the way the “clicks” are angled.

Ill. 60.5 *Click system in the prototype*

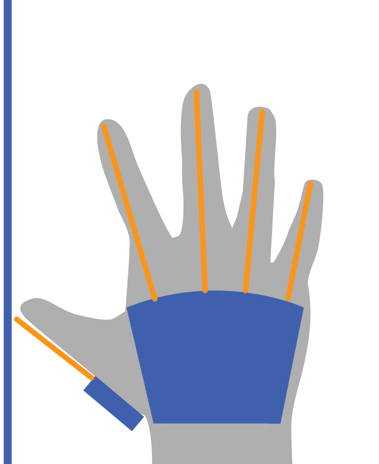
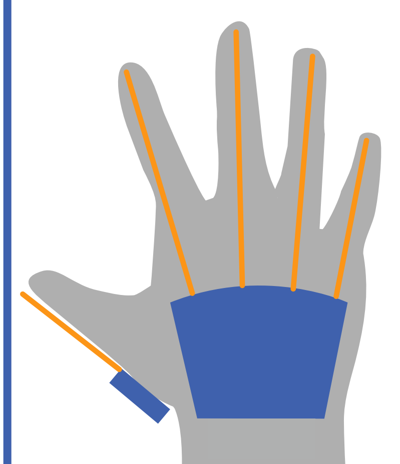
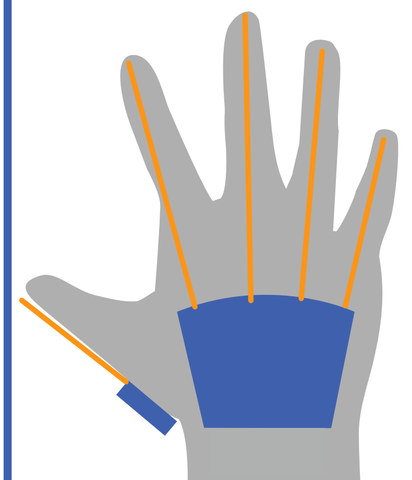
This system proved to work well on the 3D printed model. However when testing on the glove, the spring mechanism pushes against the lid and opened it. The 3D printed click system proves to be too weak because the system was made too small. For this reason it will be made bigger on the product.

Click system will be used to close the mechanism case

Research on rods length

The length of the rods is established by measuring the length between the end of the piston and the end guide positioned on the final phalanx of each digit.

The measurements are based on the average sizes for S, M and L. By placing the spring mechanism on a L size presentation of a hand, the rod length is measured and the medium and small sizes are found using the ratio between sizes. (Worksheet 91)

	SMALL	MEDIUM	LARGE
			
THUMB	55,72 mm	55,86 mm	60 mm
INDEX	84,48 mm	91,24 mm	98 mm
MIDDLE	94,82 mm	102,41 mm	110 mm
RING	86,21 mm	93,10 mm	100 mm
LITTLE	64,66 mm	69,82mm	75 mm

Rod material

For the prototype, the intended material for rods is silicon as in the final product. Tests with old wires with a silicon coating seemed to work well both for low friction when passing through the guides and transmission of force to the spring when bending. Though it is hard to find silicon wires in the right diameter, so for the model tape reinforced with a metal wire is used.

Ill. 62.1 *The rod in the prototype*

Sewing

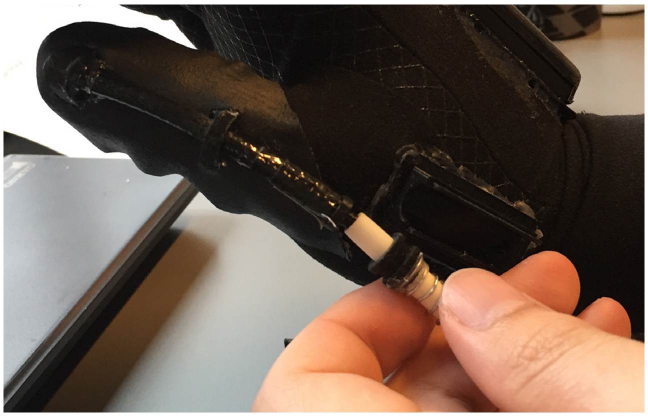
When first tested, just glueing the components onto the base glove is not enoughto give them stability. To simulate the two layers of fabric of the final product, another layer of fabric is glued on top. Garden gloves with rubber surface are cut and placed on the base glove.

Ill. 62.2 *A second layer of fabric is glued above the glove*

Adjusting spring resistance

To adjust the mechanism resistance, the user would change the whole unit (piston and spring). The piston and rod adapter are threaded to fit together. When opening the lid, it is possible to screw the unit on the threaded piece of the rod.

Ill. 62.3 *The thumb case without spring unit*



Ill. 62.4 *The spring unit is screwed to the rod*

Once the unit is screwed on the rod, it can be placed in the case.

Ill. 62.5 *The unit is placed in the case*

The lid is closed again and the product is ready to use.

Ill. 62.6 *The case is closed*

The prototype is built and ready for further testing.

Ill. 62.7 *The finished prototype*

4.4 Materials

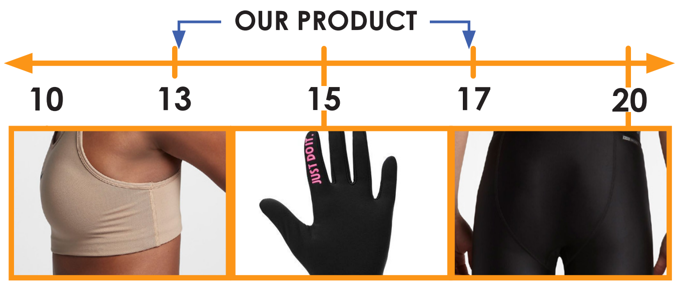
Research on materials used in sportive apparel is conducted to find materials for the product construction and delineate material specifications.

Glove

Fabrics used in sportive apparel often provide a stretchy fit to stay in place when working out. Spandex (or Lycra) is often used in those product due to its high elasticity; it also protect the skin from stings and abrasion, it is breathable, wicks moisture and dries quickly. Though, spandex is always used in combination with another fabric: a too high percentage of spandex can make the product too tight. (Mayur Basuk & Amit Sengupta, 2016)

By looking at Nike Dri-FIT technology, spandex is often used in combination with polyester, one of the most used fabric in sport apparel due to its durability, breathability, and low moisture regain (0,2 - 0,4%). In Nike products, the percentage of spandex varies between 10-20% depending on the use of the product. (Worksheet 85)

For the glove there is a need of having a low moisture regain, good stretch and resistance, and being tight enough to the hand. By looking at the most used fabric in sport equipment, it is decided to combine the low moisture regain of the polyester and the high elasticity and stretchy fit-on-body characteristics of the spandex (the same fabric combination is largely used by Nike Dri-FIT technology). The glove needs to be tighter than a normal Nike sweat-suit, but not as tight as a swimsuit so it won't be too uncomfortable. The ideal range is between 13-17% of Spandex and 87-83% of polyester. An example are the Nike running gloves made of 85% polyester/15% spandex.



Ill. 63.1 *Percentage of spandex in Nike products*

Plastic materials

Plastic materials are used to produce the mechanism case, rods and guides. (Worksheet 87)

Rods: Due to its flexibility, silicone similar to that of cables is used for the rods. Low-friction coefficient silicone coating is applied to reduce the friction when the rod passes through the guides.

Guides and mechanism case: Because of the possibility of making the plastic parts in the same tool, guides and mechanism case should all be the same material. ABS (acrylonitrile butadiene styrene) is used for the guides and mechanism case. It is a hard and flexible material, sometimes used for phone cases, and for these properties it protects the mechanism and makes it easy to take off the upper part of the case.

MATERIAL SPECIFICATION

METRIC #	NEED #	METRIC	UNIT	MARGINAL VALUE	IDEAL VALUE
19	Worksheet 85	Moisture regain of glove fabric	%	1	0,2
20	Worksheet 85	Elongation at break of glove fabric (reference from sport apparel)	%	≥ 40	≥ 50
21	Worksheet 87	Hardness of rods material (reference from pc cables)	Shore A	90	90
22	Worksheet 87	Flexibility of rods material (determined by measuring the degree of finger rotation)	°	120	140

4.5 Manufacturing

Different manufacturing methods have been considered for the production of the different components of the design proposal.

Injection molding

The plastic components of the product are produced by injection molding. This method works by feeding an injection molding machine with plastic granulate which is melted and forwarded by a turning screw shaft inside the machine. The molten plastic is injected through the nozzle into the mold. This process may take several seconds to make sure all spaces of the mold cavities are filled. Water flows through the water channels to lower the heat and harden the plastic. The hardened part is ejected by opening the mold. (Modern Moulds&Tools 2017)

The molds make the production costly: good quality steel tools can easily cost up to 40.000 DKK, and life expectancy for well maintained tools, although hard to precisely predict, but can be up to 2.000.000 cycles. Producing a high number of pieces lowers the price per piece. (Hans Ullmer, 2003)

To effectively use injection molding, the product parts should be designed with this method in mind. By simplyfing geometry and minimizing the number of parts, it is cheaper and easier to make the mold tool and prevents defects during production. Designing for injection molding also means considering the fact that the parts need to be able exit the mold tool. Not doing this could lead to a more complex and expensive mold having to make two molds per one piece or, in the worst case, not being able to make it. (Creative Mechanism, 2015)

Hydraulic manual die cutting

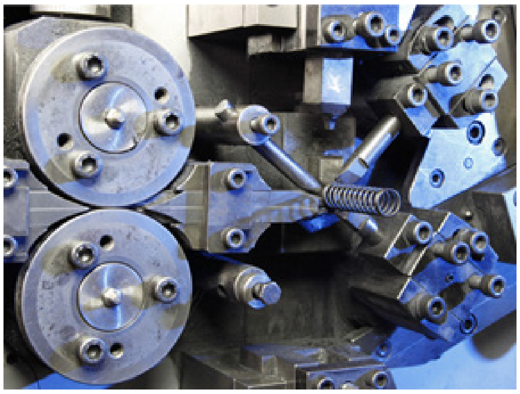
To cut the fabric of the glove into the desired shape, a hydraulic press and a cutting die is used.

The cutting die needs to be custom fabricated. Price and production time depends on size and complexity of the shape. (Automatic Arts, 2018) This is a manual but effective process as several layers of fabric can be cut at once. The machine is relatively inexpensive as it does not take a lot of force to cut fabric. An alternative to hydraulic manual die cutting is to lasercut the fabric pieces. (Worksheet 94)

Ill. 64.1 *Hydraulic manual die cutting*

Spring manufacturing

Springs are made on mechanical spring machinery by coiling, winding or bending the spring into shape, depending on the type of spring. For the product, compression springs are used and they are made by coiling metal wire on a coiling machine. The wire is fed onto rollers that pull the spring into the wire guides; there the rollers coil the wire. This creates tension in the spring wire which can be reduced by heating up the spring.



Ill. 64.2 *A spring coiler*

4.6 Conclusion

The working principle of the design proposal is constructed through prototypes and research into materials and manufacturing methods.

The exercises will be tracked by using an infrared sensor that detects the movement of the piston to which the spring is threaded: if the piston reaches a certain threshold, the infrared sensor will detect that a flexion or extension of finger is performed depending if the piston is getting closer of farther.

The springs will be screwed onto the threaded pistons; the rods will be fastened in the pistons.

The resistance of the mechanism will be adjusted by changing the spring units; the user will be able to choose between three different spring units of 5, 10, and 15 N.

The rods will be made in silicone, while the mechanism cases and the guides will be made with ABS. From research into sport apparel, the glove fabric will be made of 85% of polyester and 15% of spandex.

The plastic components will be manufactured by injection molding. Having the two gloves specular allows to use the same molding for both left and right hand. The fabric will be cutted by hydraulic manual die cutting.

References 4 - Development

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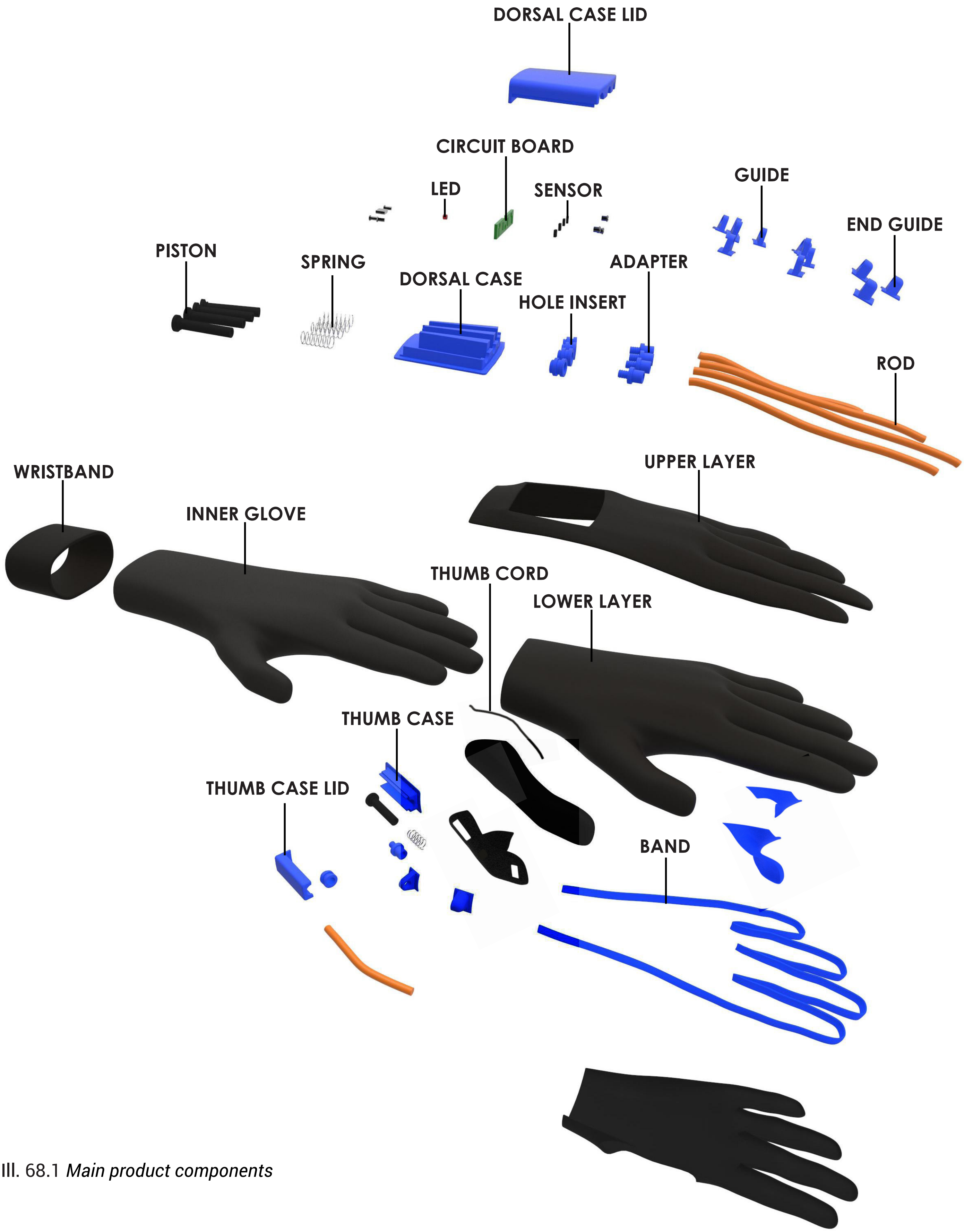
5 DETAIL

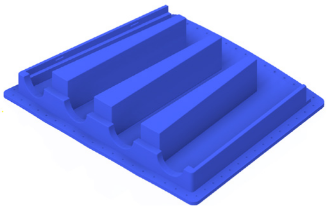
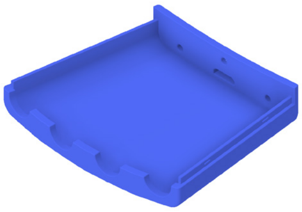
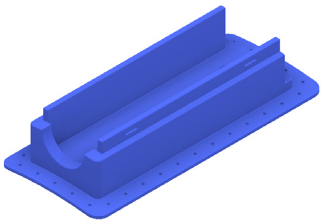
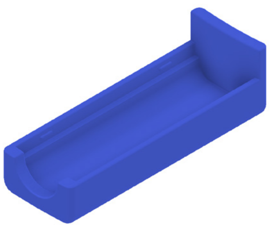
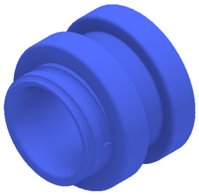
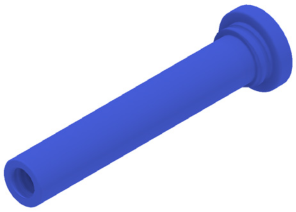
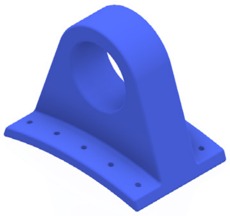
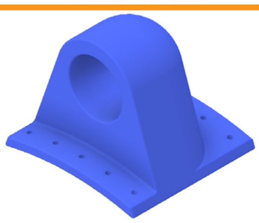
The chapter describes the components of the design proposal and how the program works. The aesthetic intended for the design proposal is delineated.

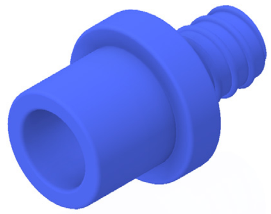
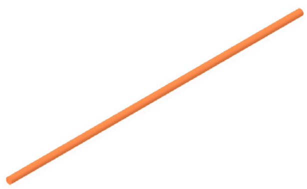
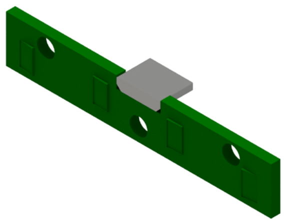
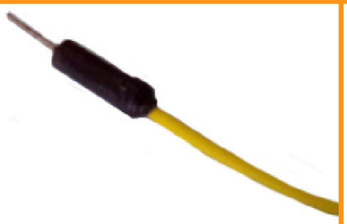
5.1 Product components

The components of the resistance mechanism inside the glove are enlisted and their functionality described



Ill. 68.1 *Main product components*

	**Dorsal case** The case that hold the mechanism. It have 4 chutes with room for the resistance mechanism of the index, middle, ring and little finger. The case is curved to accommodate the shape of the hand. The chutes are turned 5 degree on the horizontal plane in relation to eachother to accommodate the angle of the fingers and a bigger selection of hand sizes. The dorsa case has a thinner surface around with holes to sew it to the glove material.
	**Dorsal case lid** This component fits on top of the dorsal case by using a click system as seen on smart phones and other electronics. It helps shielding the resistance mechanism and it also holds the circuit board with the sensors and micro usb port. By taking this off, the gauntlet can be washed.
	**Thumb case** This is a smaller version of the dorsal case. The thumb case only houses one resistance mechanism, the one for the thumb. This also has a thinner surface around with holes for sewing it to the glove. The mechanism inside is connected to the dorsal case through a small cable that passes through the two layers of fabric.
	**Thumb case lid** This component fits on top of the thumb case with a click system. It helps shielding the mechanism inside the thumb case.
	**Hole insert** The hole inserts rest on the holes on the dorsal and thumb case. The thinner diameter at the middle of the barrel fits the holes on the dorsal and thumb case. The spring is threaded to it inside the casing. The piston passes through it.
	**Piston** This piece holds the spring and goes through the hole insert. The spring is threaded on the cap. On the other end the adapter is screwed in.
	**Guide** Between each finger joint there is a guide to help transport the rod when flexing or entending the fingers. The base is glued onto the base glove and has holes to make it possible to stitch it on for a stronger attachment.
	**End guide** The end guides function like the guides except for them being at the tips of the fingers and being closed. The rods are glued into those.

	**Adapter** The adapter functions like an attachpoint between the pistons and the rods. The rods are glued into the hole and the other end is screwed to the piston.This makes it possible to change the spring unit thus change the resistance.
	**Rod** The rods bind the fingers and spring mechanisms together, so that the mechanism will be affected by the movement of the fingers. They are attached to both the fingertips through guides and the pistons.
	**Circuit board with micro usb** Inside the dorsal case lid lies the electronical parts. The circuit board is screwed onto the lid and the sensors are attached with small sockets on the circuit board. The circuit board has a micro usb which is the main power input and data output. It is attached at a 90 angle to give access from the back side of the dorsal case lid.
	**Thumb cord** It connects the infrared sensor in the thumb case to the circuit board in the main mechanism case. The cord passes between the upper and lower layer of fabric.
	**APDS-9960 IR proximity sensor** The chosen sensor for the product. It has the ideal size for fitting in the case. 4 sensors are attached on the circuit board getting data from the 4 shote, 1 is in the thumb case lid and it is connected to the circuit board through a small cable.
	**Dual micro USB-to-USB cable** As the users should train both hands to get a balanced exercise, the micro USB-to-USB cable has a dual micro USB side.
	**Springs** The chosen springs give a force resistance of 5 N, 10 N or 15 N at 15 mm compression. They give the same amount of force resistace in extension.
	**LED light** A LED is connected to the circuit board and placed on the dorsal case lid. The LED gives visual feedbacks when the gauntlet is connected.

Glove construction

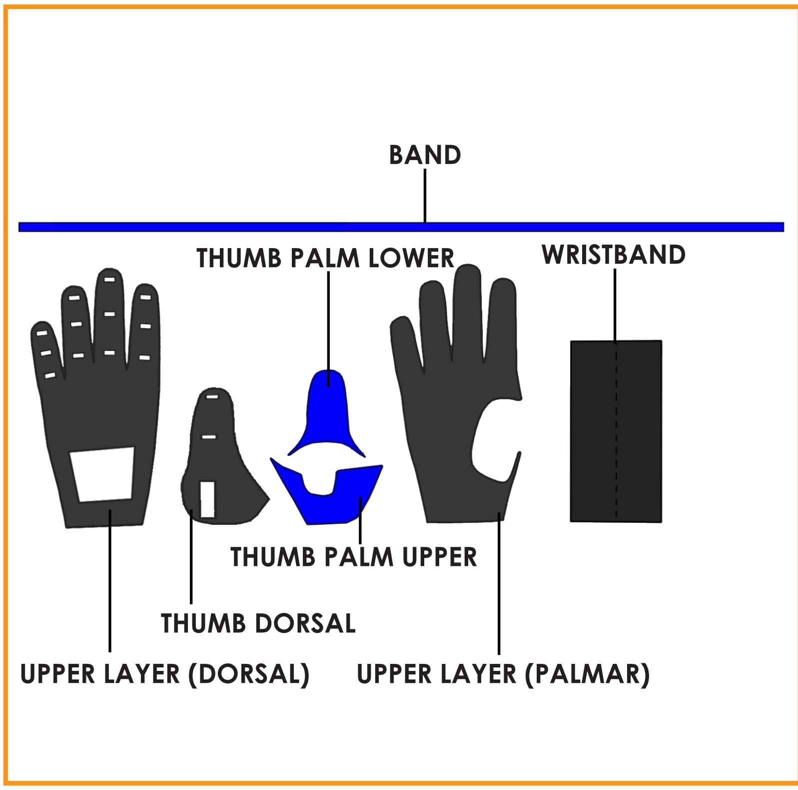
Typical cutting patterns for glove manufacturing usually have one or two pieces for the dorsal and palmar side of the hand, and one or two pieces for the thumb. Depending on the need for movement, an extra piece is cut for the thumb to increase mobility. (Worksheet 85)

Ill. 71.1 *General glove construction*

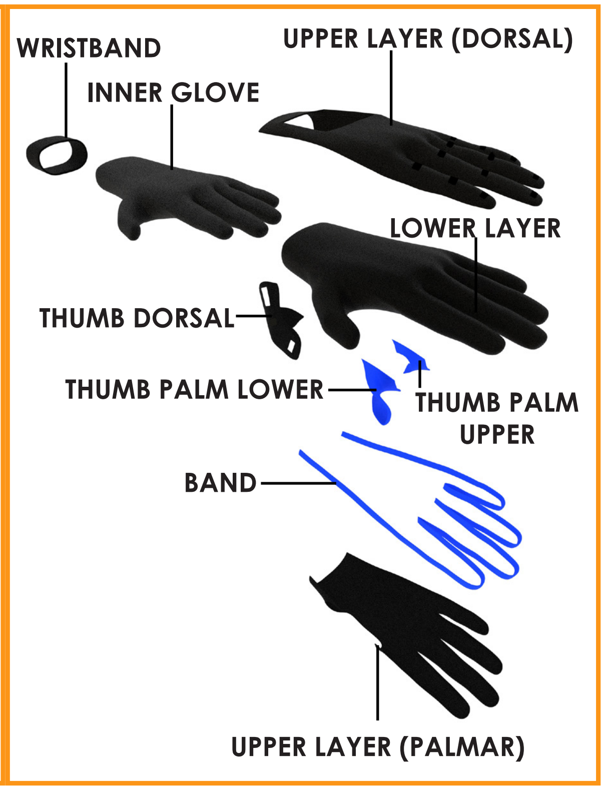
Ill. 71.2 *Sports glove with 3 pieces in the thumb*

The glove for the product will be made of three layers made with the same fabric:
- An inner glove that can be taken out and washed.
- A lower layer where the components are glued and sewn onto
- An upper layer of the glove to add stability to the components.

The construction of the inner glove and lower layer will follow the same construction of the upper layer.



Ill. 71.3 *Construction of the upper layer of glove*



Ill. 71.4 *Components of the glove*

5.2 Spring dimensions

For designing a spring it is required to know the force and spring rate or total deflection of the spring. The spring index for the spring should be between 4 to 12. Having this number lower than 4 would make it difficult to manufacture and having it higher than 12 would result in a spring that is flimsy and tangle easily. Smaller spring index is good for higher forces but a value between 8 and 10 is suitable for most applications. (Schmid et al., 2013)

With small variation in force over spring's range of motion, it is suggested to have a spring rate as low as possible. A preloaded spring with low stiffness is preferable.

The number of active coils should be above 2 to avoid difficulties with manufacturing.

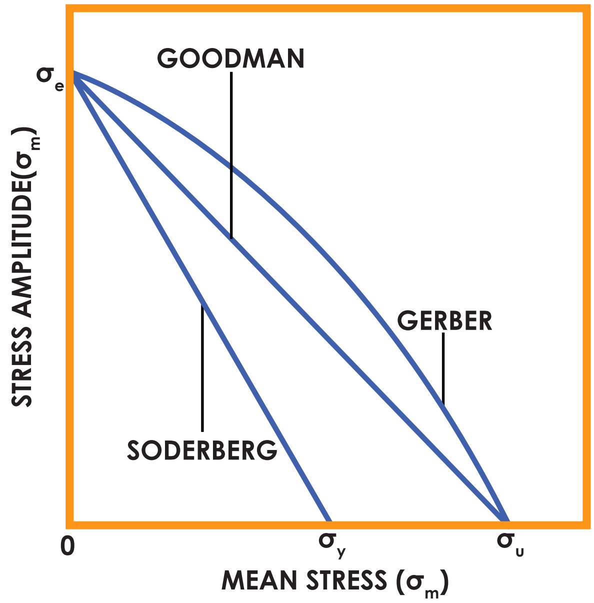
When a spring is placed in a cage or on a rod, 10% of the spring diameter must be specified as clearance. This also helps to compensate for coating thickness. It is advised to have some preload of the spring at free height, as the spring have no restraining force.

It is advised to avoid compressing a spring to its solid length. When the spring get closer to solid length the pitch between coils will be smaller and this will lead to progressive coil to coil contact. Any contact leads to impact and surface deterioration and to an increase in stiffness. To avoid this the working length should not exceed the the solid length by a clash allowance of at least 10% of the maximum working deflection. In applications of high speed and/or inertias this number might need to be increased.

Springs can not buckle when placed over a rod. (Appendix 1.1)

Calculation of spring life

Helical compression spring are mostly subjected to fatigue loading. For many springs the number of cycles of required life is small. An example is a padlock spring or toggle-switch spring that requires several thousand cycles. But a valve spring of an automotive engine most sustain millions of cycles without failing. For this reason it must be designed for infinite life. (Budynas & Nisbett, 2011)



To find out when a spring will fail, it is held up against failure criterions: Gerber, Goodman and Soderberg, where Soderberg is the most conservative, and Goodman the least when using the Zimmerli data. The result is a factor of safety where numbers above 1 theoretically have infinite life and the bigger the number the more safety there is for the spring to hold.

The material chosen for the spring is AISI type 302 Stainless Steel. (ASM)

The springs in the application are going to be subjected to 3 different range of forces which will mean different requirements for the springs. Common for all the springs except for the thumb springs is that they will be 25 mm long in free length and they need to be able to deflect by 15 mm when subjected to 5N, 10N and 15N reflectively. In the application there is room for the springs to have a maximum diameter for 10mm -0.5mm to reduce friction.

The only exception to this is the thumb, that needs to have a free length of 20mm and deflect only 10 mm but otherwise also be 5, 10 and 15 newton.

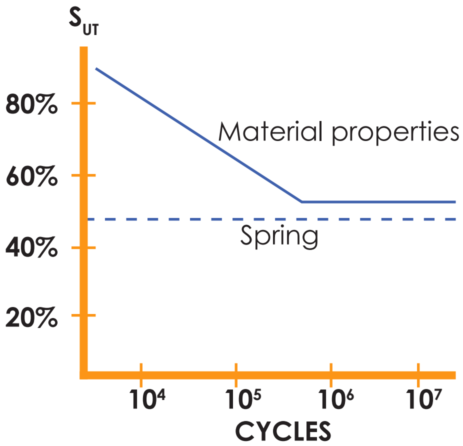
	SPRING 5N	SPRING 10N	SPRING 15N
Outer diameter	9,3 mm	9,5 mm	9,5 mm
Wire diameter	0,7 mm	0,8 mm	0,85 mm
Spring constant	0,364 N/mm	0,706 N/mm	1,004 N/mm

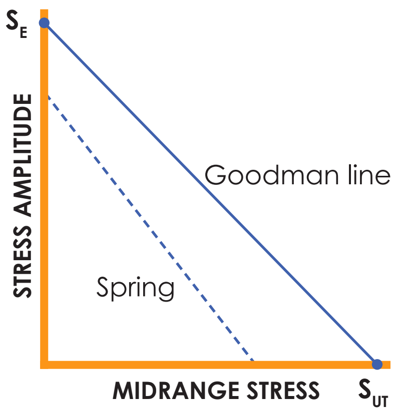
Factor of safety against fatigue

The best data on the torsional endurance limits of spring steels are reported by Zimmerli. He discovered the fact that size, material and tensile strength have no effect on endurance limits (for infinite life) of spring steels wire diameter under 10 mm.

The Zimmerli data is used to calculate shear endurance limit which again is used to calculate shear stress amplitude limit. Comparing the shear amplitude limit with the shear stress amplitude the result is a factor of safety where results over 1 means the force are below the goodman line. This means the spring have theoretically infinite life. (Robert L. Norton, 2013)

	SPRING 5N	SPRING 10N	SPRING 15N
Factor of safety Goodman	1,78	1,4	1,15





Shot Peening can be used to improve the lifetime of a spring, it can improve the torsional fatigue strength by 20% or more. The size of the shot is about 0,40 mm which means the springs need to be designed to be able to be completely covered of the spring surface by the shots in order to make the method effective.

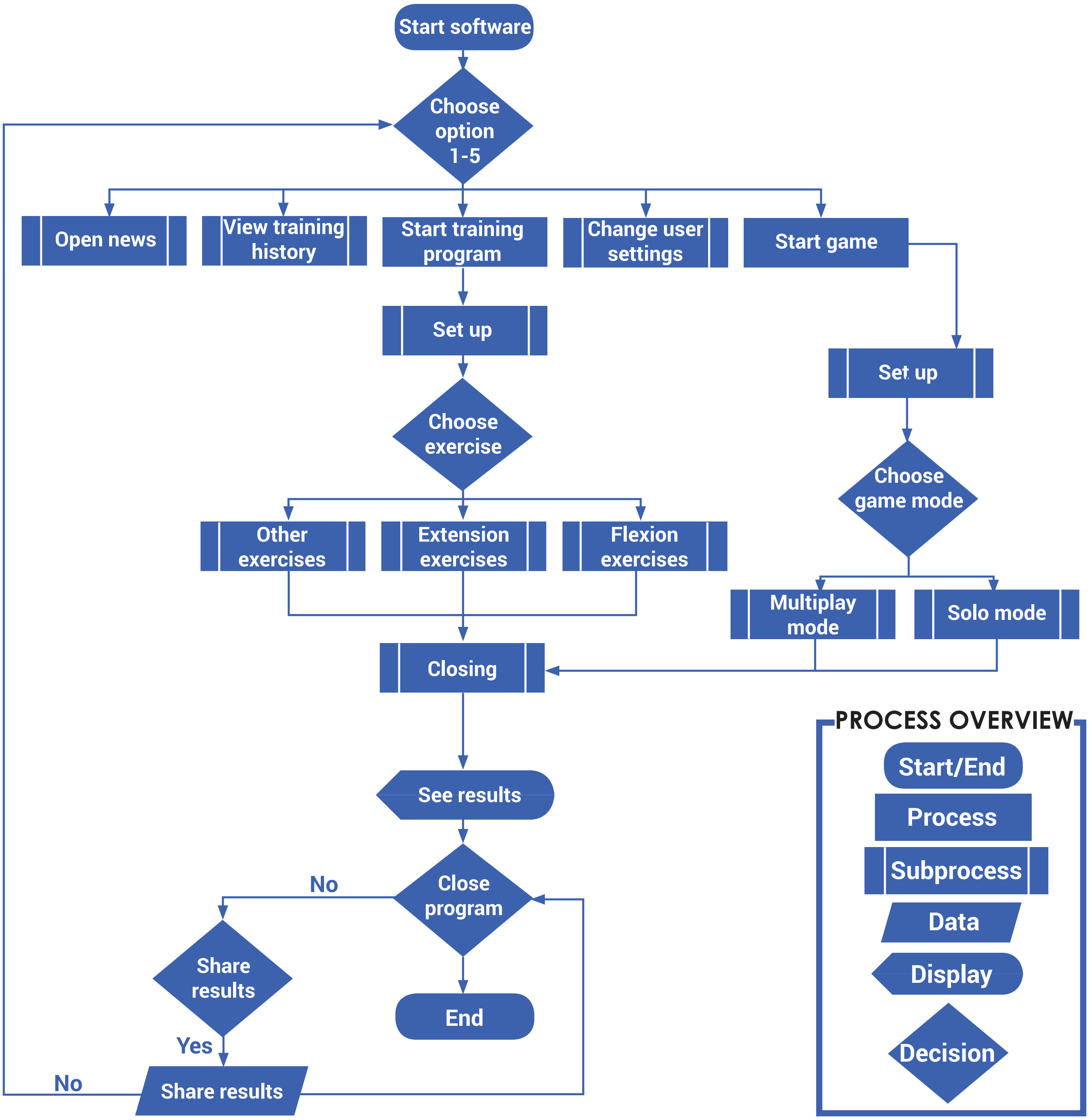
5.3 Flowchart

The gauntlet works together with a computer application in which exercises are showed, tracked and gamified. The application is inspired by fitness app already in the market. The flowchart shows the actions the user goes through when navigating in the application.

In the app the user can:

- Choose the kind of exercises they want to do
- See the results of the exercises
- Share results with friends
- Play a mini-game in solo or with friends

For further details see Appendix 1.2.



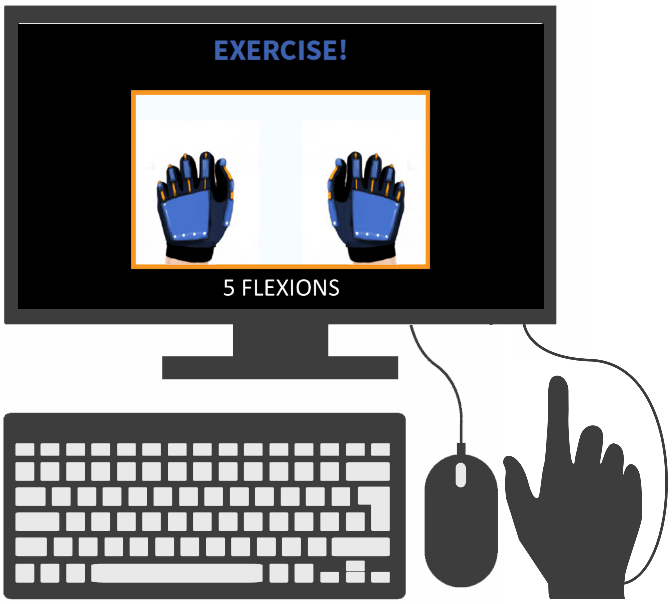
App interface

A mockup of an app interface is constructed according to the program flowchart. The gauntlet is intended to be connected to the computer where the app runs. By having the app in the computer, the player can easily access the app while taking a break from the game or waiting for the next game match.

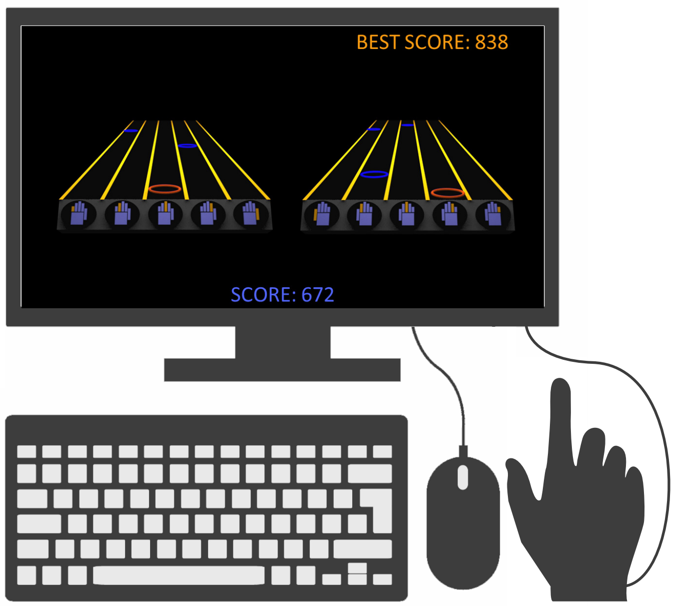
Here some interface samples are explained. For more, see Appendix 1.3.

Ill. 75.1 - When entering the app, the user can see their most recent activities. They can choose if working out with classic training tutorial, play short games, see the feeds from their friends or change settings as selecting the spring they are using.

Ill. 75.2 - The user can see their training history and check the performance status. The increasing or decreasing of the performance depends on the accuracy the exercises are performed.



Ill. 75.3 - When working out, the exercises are shown in the desktop trough short animations. Once the gauntlet registers that all the exercises has been done, the player switch to another exercise or to the ending page where can choose if sharing the results or going back to the home page.



Ill. 75.4 - A concept of a 5 minutes mini-game inspired by *Guitar Hero* is developed to test high gamification. The game can be played in solo or multiplay mode, in easy mode (using only one hand) or hard (using both hands).

5.4 Product testing

A test on user interaction is conducted to research if the user understands the functionality of the gauntlet combined with an application interface, and to evaluate if integrating a minigame in the exercises would have a positive effect on motivation. (Worksheet 96)

It is not possible to use infrared sensors in the test because the one used in the previous test is too big and would only detect one finger movement, and it is outside the competence of the team to program a small sensor that is not supported by an Arduino micro processor.

Six respondents participates at the test. 50% are mid-core CS:GO players, 50% are casual players. The respondents' age range is 23 -36 years old.

The user test is divided in two:

- User test on program interface
- Game test to understand if in this context a high gamification is motivational.

Test on program interface

The test is intended to give insights on the interaction between the user and the app, and in particular if and how the respondent reacts to what the app shows.

An app navigation is simulated by building a mockup in powerpoint through the use of hyperlinks: this way, the respondent is able to simulate the navigation in the app system. For example from the homepage, when clicking on "work out" the respondent is redirected to the "choose exercise" page; when clicking on "play", the respondent is redirected to the game page. Illustrations are used to explain the exercises the respondent must execute. For the last 2 respondents the visuals are animated based on feedbaks. The respondents are engaged when following the instructions for the hand exercises. The gifs are understood better than the illustrations. Due to lack of connection between the gauntlet and the computer, it is not possible to give visual feedback in case the respondent is doing the exercise correctly. This should be integrated in the final product.

All the respondents understand how to navigate in the application and they respond quickly to the app instructions. When doing the exercises, they feel the resistance given by the springs.

The hand exercises in the application are three samples, but more are integrated in the final application.

Test on program interface

For simulating a minigame, a video in 3D Studio Max is prepared. The game is a rhythm game inspired by the Guitar Hero series. Blue circles slides down on five circuits, each representing a finger. When the circle becomes orange in proximity of the end, the user has to move the finger of the correspondent circuit.

To understand if the game is motivational, motivation is measured by the degree to which the game is evaluated positively in a scale from 1 to 5.

1 - Poor
2 - Fair
3 - Good
4 - Very good
5 - Excellent

The respondents are able to understand the game rules without given infos, with the exception of one. All the respondents move the fingers as imposed by the game rule.

The average score given by respondents is 4.1, in accordance with the product specification.

Conclusion

All the respondents were positive and engaged when using the glove and application. They were especially engaged when using game. Overall they looked past the minor issues from simulating the experience. During the test, the gauntlet was not connected to the computer as the final product is; having a wire might influence the way the respondents use the gauntlet.

Based on their feedbacks, the game seems to be effective in a short term, though its effect over time needs to be clarified. More similar minigames can be developed to add longevity. There is a need to make sure people won't play those games for too long otherwise it won't be beneficial anymore to the hand muscles.

Although the game in itself seems efficient in motivating, it is decided to keep the training mode to allow users to decide between two degrees of gamification (low and high).

Relevant feedbacks from respondents are collected:

"Having score in the solo game is very good because then you can see yourself improving. The game is about the same level of fun as a casual game (eg. facebook game)."

"Extension/Flexion exercises seem a bit hard to understand at the beginning." [tested before the gifs were integrated]

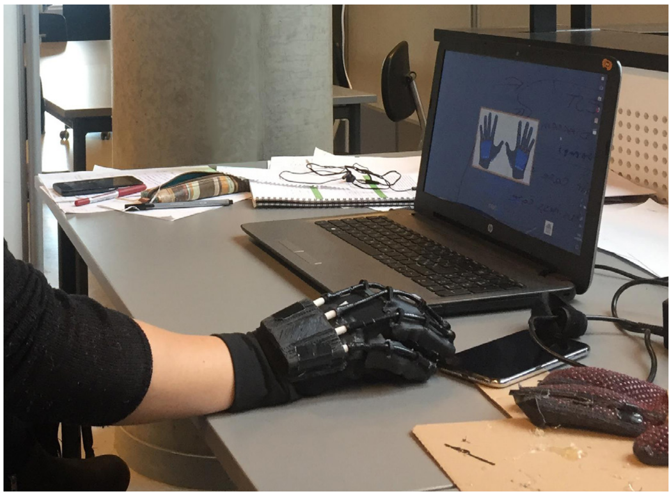
"It would be nice to have visual feedbacks if I am doing the exercises correctly."

"The game is probably more fun in multiplayer."

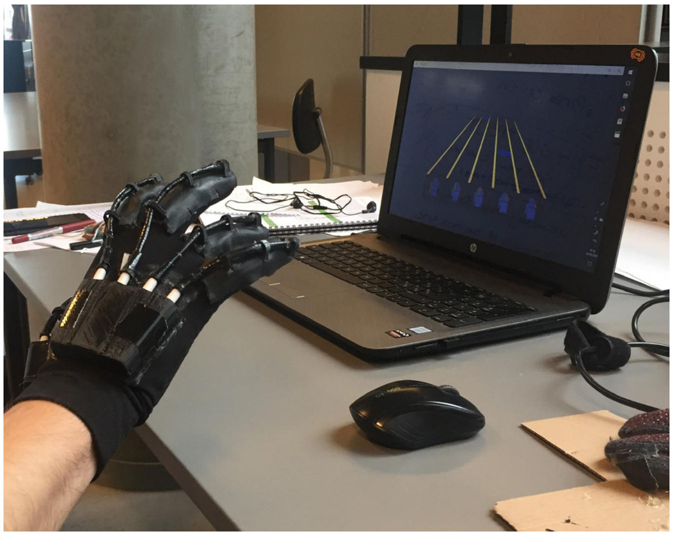
"The game is simple but fun. It is more fun than I expected"

The game is fun in short term

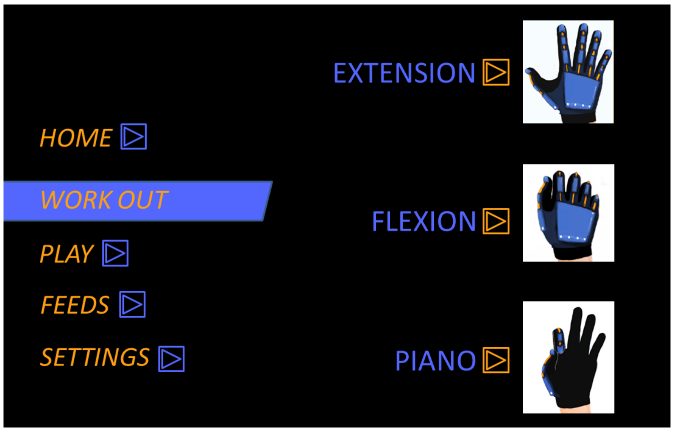
The training mode is kept to add diversification



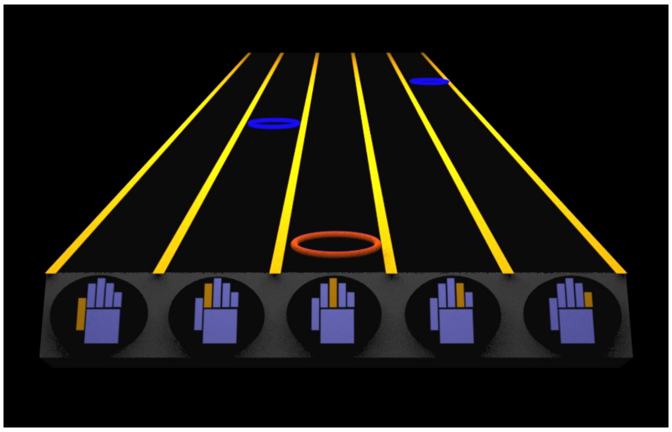
Ill. 77.1 *A respondent navigating in the app*



Ill. 77.2 *A respondent playing the game*



Ill. 77.3 *Sample of the app interface mockup*



Ill. 77.4 *The minigame*

5.5 Aesthetic

Different aesthetic concepts are explored. The concepts are based on sports, fitness, and gaming culture. The concepts are then evaluated, and the most interesting features are "assembled" to create the final aesthetic concept. (Worksheet 90)

Ill. 78.1 - Inspired by a gaming chair. Characterized by soft curves and bright colors combined with black, often associated with the gaming experience.

Ill. 78.2 - Inspired by arcade games. Characterized by neon lights and very bright colors. LED lights are used for visual feedback when the glove is working.

Ill. 78.3 - Inspired by Formula 1 cars. Characterized by a dynamic shape of straight lines and curves, it gives a sport feeling

Ill. 78.4 - Inspired by fitness machine. Characterized by a minimal design, wires are hidden.

Ill. 78.5 - Inspired by the Marvel's Infinity Glove. Characterized by neon lights on knuckles, showy look. "Nerd" culture.

Ill. 78.6 *The final aesthetic*

The following aesthetic features from the different concepts are integrated in the final aesthetic proposal (Worksheet 90):

- LED light for visual feedback
- Wires are not hidden but emphasized to give identity to the product
- Bright colors inspired by CS:GO teams' colors
- Straight lines are combined with soft curves to follow the shape of the fingertips
- The back of the hand has enough space for product logo or other brand marks

Bright colors are used for a more sportive feeling - this also seems to be the aesthetic preferred by gamers (Worksheet 66)

5.6 Conclusion

The detail phase involved a deeper research into product components, how they are assembled and the construction of the glove.

The mechanical characteristics of the springs and their lifespan is calculated: according to the calculations they theoretically have infinite life.

The program main functions were developed, in particular the exercises and minigame, and a flowchart was constructed from the user point of view.

The final prototype of the glove, together with a mockup of the computer application and minigame, were tested on midcore and casual players. The game is motivating but the lifetime cannot be predicted, thus the training mode is kept to allow the user to choose between two degrees of gamification (low and high)

The aesthetic of the product was defined through interviews of users and research into sport, eSport and gaming aesthetic. The result is a sportive-looking product characterized by bright colors and unusual details such as the rods and mechanism cases.

In order to validate the product, the Occupational Therapist Anne-Sofie was contacted again and presented with the final product. She said it looks very good and likes the idea of being able to change the resistance by changing the springs.

In occupational therapy motivation is a huge factor for doing exercises, otherwise the training would not be necessary.

Having the resistance connected to the fingertips through the guides is very good, it helps create a more uniform pull along the fingers. Without the guides along the fingers there would be a risk of making a 'crooked' pull and cause injuries. It definitely seems like the right muscles are being activated. (Worksheet 97)

References 5 - Detail

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ASM Data Sheet, *AISI Type 302 Stainless Steel, annealed bar* (online), Available at: http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=mq302ac [Accessed 25 May 2018]

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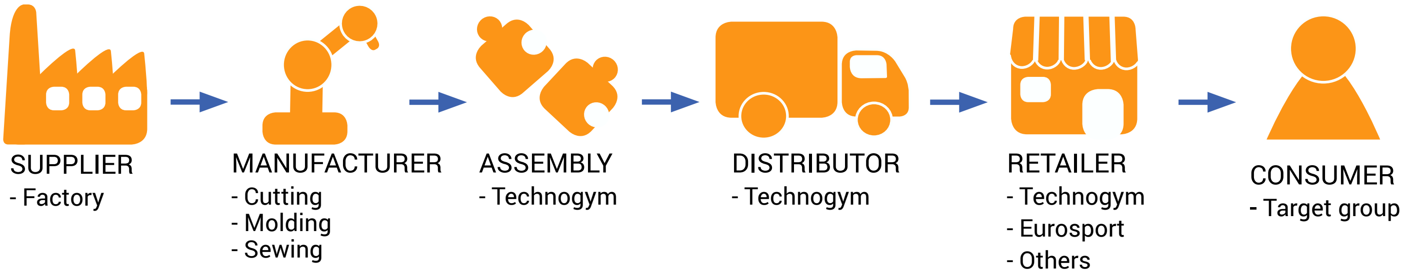
6 IMPLEMENT

Business strategy and market potential is delineated according to the final concept, construction and manufacturing methods. From those, a cost estimation of the final product is made.

6.1 Business strategy

SUPPLY CHAIN



Vis is a small design firm consisting of two designers. VIS is the company behind the VIS gauntlet. The main objective is to place the product on the market. (Worksheet 72, 76, 93, 94)

The business strategy presented in this report is centered around partnering with Technogym. In this scenario, Vis can take advantage of the technogym supply chain and production facilities of Technogym in return revenue.

Technogym is a global leader on the fitness market promoting wellness, from product design and medical-scientific innovation to social projects. The company is sponsoring sports events and teams in golf, football, Formula 1, Olympics etc.

Given Technogym's profile and their reach, they are the ideal business partner. Vis can help Technogym bringing both wellness and fitness into eSports.

In order for Technogym to get the product on the market, the product will have to go through different stages of the supply chain from raw materials to a finished product for the target group.

Technogym has a system of more than 400 suppliers from around the world. Technogym's two main production facilities in Cesena (Italy) and in Slovakia are in charge of assemblying.

Vis is going to use the facility in Cesena for assembly, while Indian manufacturers are in charge of manufacturing of plastic components, cutting and sewing.

The manufacturer will then order the necessary materials from suppliers to assemble the gloves.

The total price material price is: 99,53 DKK/pair.

The manufacturer needs equipment in order to be able to produce the gloves. For simplicity the manufacturer is producing all of the parts from the raw materials. The price for machinery and operation including wages, electricity etc. is added to the price for a pair of gloves. The profit margin is set to 20% considering the manufacturer gains and expenses.

Cost of operations (pair of gloves)
60,60 DKK/pair
Production cost with materials
160,13 DKK/pair

Total Cost
192,16 DKK/pair

REVENUE

Revenue is calculated to be sales price minus cost. This revenue will cover wages, housing etc. for both the retailer and Technogym.

Sales price:
691,77 DKK
VIS - Royalties 8% of revenue 39,97 DKK
Technogym - 46% of revenue 229,82 DKK
Retailer - 46% of revenue 229,82 DKK

Break even

By selling 14600 pairs by year 3, Vis will breakeven and earn 19370,88 DKK while having paid for wages to 2 designers in Denmark for 2 months. (Worksheet 94).

With the expected amount of sales, Vis will be able to pay for the development of the software program (130.000 DKK) and maintenance, which consist of server cost and hiring a programmer to work 20 h/month on updating the program.

Focusing on royalties is risky as the product might not fare on the market as expected. Once it is designed and handed over to Technogym, then there is no more expenses for VIS, only income.

The number of sales comes from an expectation of being able to sell to 0,1% of eSport enthusiasts in Western Europe. The eSport scene is well developed in Western Europe and the countries have similar markets; for this reason, the zone is considered a good entry scenario for the product. (Newzoo, 2018)

Market strategy

By partnering with a company established in the market like Technogym, it is easier to enter on the fitness market than launching a startup. For the initial launch, the product is expected to enter the market as version 1.0. Based on feedbacks from the initial launch, an improved version of the product can be launched later. One way to improve the product would be to develop the program as a phone app.

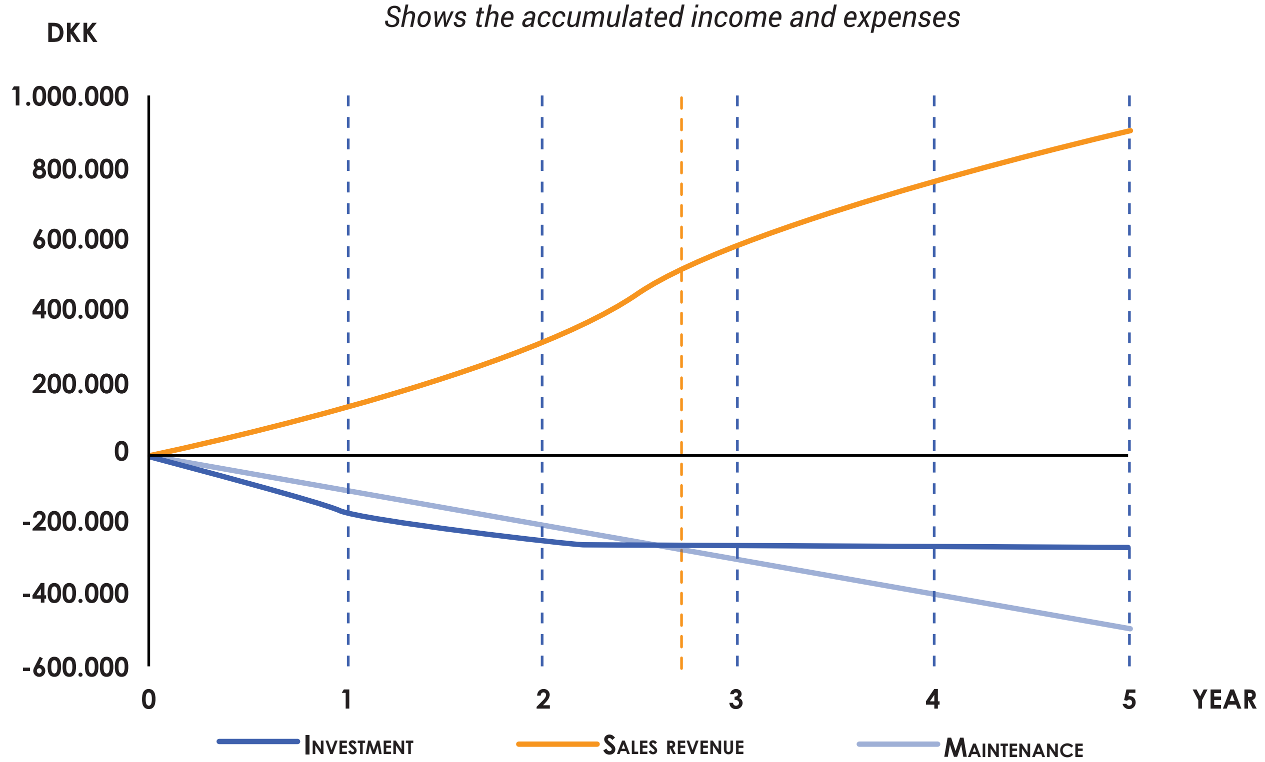
The glove will be produced in 3 difference unisex sizes: small (25%), medium (55%) and large (20%), to be able to reach more customers with different hand sizes. (R. Berguer and A. Hreljac, 2004) The only change in production for changing glove size is the length of the rods and the gloves.

HAND SIZES (AVERAGE)

	SMALL	MEDIUM	LARGE
LENGTH	15,80 mm	17,15 mm	18,40 mm
WIDTH	15,25 mm	17,80 mm	20,25 mm

BREAKEVEN CHART

Shows the accumulated income and expenses



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EPILOGUE

Conclusion

Process

This report has described the design process of a hand-training device. The vision that guided the process was to make eSport a healthy sport by reducing the risk of injuries related to the overuse of the mouse.

The eSport game CS:GO was taken as study sample due to its longevity and importance in the global eSport scene.

When developing the project, LAN parties were visited to get valuable insights from players and coaches. Medical professionals were also contacted to validate concepts along the development phase.

During the process, the solution space was changed from developing a new mouse to making a hand training device: this decision was taken because of the limitations in creating a new mouse, while it was noticed that there was a market opportunity in making a product that would assist the players in doing the hand exercises recommended by medical professionals, thus prevent the injuries from occurring.

The main target group is the professional players since getting injuries for them affect their career, and through them other types of players can be reached as many professional players have a big following on social media.

Mockups had been made to test and improve parts of the product. This gave a better understanding of the mechanism and the connection between different components.

It is planned to collaborate with the company Technogym as they are leaders in the fitness market and sponsor sport events - so they can potentially be interested in entering eSport as well. Working with Technogym would help reach more players through their brand and they already have a big network of suppliers that could potentially be used. Alternatively VIS would have to work alone which presents a bigger risk of not being able to reach the intended customers.

Product

The mission of the project was to improve the health of eSport players by aiding them doing hand exercises.

The design proposal is a gauntlet providing a resistance mechanism to exercise the hand muscles; the device is connected to a computer application from which the user can check their own progression, follow a training program and share results or play alone or with friends, making the product fun to use. The length of the USB cables make it less of a restriction to have it plugged into the computer to do the exercises. When using the product the player will gain visual feedback on the screen showing how well they are doing this exercises. This is thanks to the tracking provided by the infrared sensors. The rods goes through the guides helping to distribute the forces along the fingers. Thanks to a spring resistance on each finger, and the possibility to train each finger in extension and flexion, the product gives the opportunity to make more exercises than any other product in the market. The rods are both hard and flexible enough to allow this. The product focuses on strengthening exercises as they help building up muscles and improve motor skills.

Having build the training device onto a glove it takes the product easy to put on. When using the product it takes the player less than 5 minutes to do the exercises.

Reflection

Velcro in the wrist

While testing the prototype, it is noticed that when flexing the hand the mechanism case is pulled up. This is because the fabric used is not tight enough.

Ill. 87.1

By adding a velcro fastener around the wrist area, it would be possible for the user to adjust the size and make it stay tight and firm on the hand. This way the glove won't move when exercises are executed and might fit better in different hands.

Rods

Dimensioning overall is not hard when going by the average hand size for S, M and L, but hand anatomy can differ from person to person and some people will have shorter fingers or longer fingers. Though the end guides are placed over the last phalanx of each digit, giving them a certain degree of freedom as there is no need for them to be placed on an exact point on the last phalanx.

Measuring muscle activity

For testing the effect of the product on muscles, a test could be conducted together with a research institute. This was not possible while developing the project due to lack of answer from research companies.

User test

In the user test, infrared sensors weren't use because the available one was too big to fit into the mechanism case. The user test gave insights on user interaction with the app and the gauntlet in general, but for further investigation on direct visual feedback sensors can be integrated for a better interaction test.

Other possible users

The product can potentially be sold to other people overusing their hand such as office workers, musicians, etc. Though it is unknown the effect of gamification in motivating those categories.

Motivation in long term

The test on user interaction evaluated motivation based on subjective experience and the respondents degree of enjoyment. Though the longevity of this method is not tested due to lack of time. To test motivation in long term, it is necessary to observe how many respondants would still do the gamified exercises after some months.

Project management

During the project the Vis Gauntlet, team members were not assigned to certain tasks such a project manager. This was due to the team only consisting of 2 members. This also meant decision making had to be unanimous. In a small team, all members were needed to be 100% part of the project at all times. This did not exclude using project management methods to have a clear process. (Appendix 1.4)

Field studies

The team did not have prior knowledge about eSports other than both playing video games from time to time. This meant there was a need to research and talk to people with knowledge about it. The team visited several LAN parties where organizers and players were interviewed to understand the players' mindset. The team also contacted other stakeholders such medical professionals who were able to give insight into what is needed to train optimally.

The visits to the LAN parties were mostly done in a period of the project where the direction was uncertain which meant the interviews were not related to a specific direction of the project, but rather helped in choosing direction. It was not possible to meet the medical professionals in person as some were in California, and the ones in the country were very busy. Instead the project was presented to them through description, drawings and renders which might have affected the perception of the product. It was possible to get insights about functionality, but this process might have gone smoother and more natural in a face-to-face setting with our prototype presented.

Meister tasks (Kanban board)

The tasks for the team members were managed through the use of meister tasks, which is an online kanban board where the team made columns for to do, doing, done. This gave an overview of planned tasks, ongoing tasks and finished tasks. For the majority of the project this worked very well and having it online instead of on a wall meant it could be checked and updated from home.

Gantt Chart

For planning the major deadlines and activities of the project, a Gantt Chart was used. This tool gave an overview of the big picture but it was never detailed further as the team did not feel the need for doing so.

Worksheet

All the tasks were documented in worksheets which were divided into objective, data, and evaluation/conclusion. An objective about the intention of the activity was written before the activity to have an idea about why the tasks was done. When the tasks was started then the task data was written in the data field. Afterwards the task was evaluated in the evaluation/conclusion part to clarify if the objective was fulfilled, why and why not, clarify sources of errors or if the task needs to be performed in another way or how to proceed. This way to document work allowed to share knowledge with precision and clarity.

Product specification

The product specification was made according to the method described in Product Design and Development by Ulrich and Eppinger. The demands came mostly from stakeholders and was then transformed into needs. Some other needs came from research. The needs were changed into metrics and got a marginal and ideal value.

The needs were not used as expected and were rarely updated as they were understood in the group: it was possible to develop a product based on those needs. Having them updated on paper would have made it easier to keep track of the development of the needs.

Mockups

Through the development, the team made mockups and prototypes to understand and explain the functionality of the product. Tests were conducted to understand different parts and it gave an understanding as to what would work and what would not.

It was preferred to do more mockups and prototypes, but they were time consuming. Though the made mockups gave very good data about the construction, and the functional prototype could be tested on the user group. For the early mockups the mechanism was built on garden gloves, but the prototype was built on running gloves to get the right feel. To further test the mockups it would be necessary to come closer to the right materials and production methods.

Illustrations

All not listed illustrations are of own production

Ill. 7.1: https://www.riviera24.it/photogallery_new/images/2018/03/esport-416906.660x368.jpg
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