Developing and Demonstrating the Sport-Specific Potential of SixFeet

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Abstract

As of the beginning of 2020, lockdowns and periods of social-distancing hang as a constant threat over our heads. Anti-covid measures prevent us from doing our day-to-day activities, including sports. From extensive research as well as our own experiences it can be established that these anti-covid measures, such as a lockdown, have a detrimental effect on our physiological and mental well-being. This graduation project aims to alleviate some of this physiological and mental strain by further developing and demonstrating SixFeet. SixFeet is a platform that allows for dynamic and social sports training while always maintaining 1.5-metres distance. By building on the existing platform, this research aims to develop and demonstrate meaningful and sport-specific applications for SixFeet, specifically for field hockey for demonstration purposes. In addition, this research aims to identify what meaningful in this context entails, so that this research can be replicated to create more exercises for different sports.

To evaluate the outcomes of this research, sport-specific exercises using SixFeet are compared to alternative, yet representative exercises that also keep players at a distance, however, without the external mediation of a system. The exercises are compared on several elements, such as the level of enjoyment they bring their players. The results demonstrated that SixFeet scored better in all the categories evaluated. In addition, there is a strong correlation between the perceived level of enjoyment and the perceived difficulty of maintaining a 1.5-metres distance.

These results show that SixFeet could serve as a useful tool in times of lockdown, to not only allow users to continue sporting, but also exercise in a meaningful, yet socially engaging way. In addition, the outcomes of this research can be replicated for other sports.

Acknowledgements

There are many people without whom SixFeet would not be what it is today. First and foremost, I would like to extend my sincerest gratitude to my supervisor, Dees Postma, and my critical observer, Dennis Reidsma for helping me take SixFeet to the next level. This also extends to all lecturers and teachers from the past 3 years, for providing me with the tools to complete this Graduation Project. A special thanks goes to Alfred de Vries for helping me make SixFeet tangible and 'hockey-proof'. I would also like to thank Bart van Mossel and Robert van Der Horst for co-designing and developing a real-life application for SixFeet. In addition, I would like to thank Stijn Michiels and Laura Leduc, for being my battery pitstop crew during the user testing. Additionally, I would like to thank my parents for their continued support. Lastly, I would like to thank the original SixFeet team, for creating something worth continuing.

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2. Introduction

Periods of quarantining and social distancing have become habitual in today's society. Lockdowns affect our lives in numerous ways, one of which is our exercising and sporting behaviour. The infection risk of COVID-19 is exceptionally high in contact and team sports [1]. Anti-COVID-19 measures have made sporting and exercising in a social setting nearly impossible. Simultaneously, many studies recommend some form of physical activity during periods of quarantine [2]-[8].

While individual sports such as cycling and jogging were largely still possible, team sports were hit especially hard during periods of forced lockdown. Due to the intimate nature of team sports, keeping 1.5 metres distance is virtually impossible [1]. This resulted in the decision to put team sports on hold for long periods at a time [9]. Conversely, the perceived (mental) health benefits of team sports could prove an important tool to increase people's overall well-being in a period where the general well-being is often already somewhat compromised due to the lack of social interaction and forced confinement [4].

This issue is prevalent in both elite athletes and amateur or recreational players. A report by the NOC*NSF [9], one of the more prominent sports organisations in the Netherlands, showed that over half of the respondents indicated sporting less as a result of closed sports clubs. Another report by the same institution [10] showed that to regain the old rhythm, sports clubs need to open again and sporting with others should be possible. The qualities of sports that were among the most missed were practising the sport itself, the social ambience and training together.

There are solutions to address this issue and increase meaningful physical activity and social interaction during lockdown. However, meaningful physical activity and social interaction often prove to be mutually exclusive, only featuring one of the two at a time. In addition, training sport-specific qualities can be challenging [11]. Training these qualities is essential to prevent detraining effects and injuries returning from quarantine [12]. In addition, team sports offer many positive social and psychological health outcomes [13]. Currently, no system offers a corona-safe, meaningful and social training alternative for traditional team sports.

To address this shortcoming, SixFeet was developed. SixFeet [14] is an interactive sports platform that allows for corona-safe, multiplayer gameplay where users dynamically share the same playing field. Using a smart-allocation algorithm, SixFeet ensures that players are at a 1.5-metre distance without players actively taking note of this. The system was initially developed as a creative solution to one limiting design constraint; the pandemic and social distancing measures. The system features LED stations arranged in a circular configuration. See Figure 1. Each of the LED stations has an LED-light ring and a tactile foot switch. See Figure 2.

Figure 1: SixFeet configuration

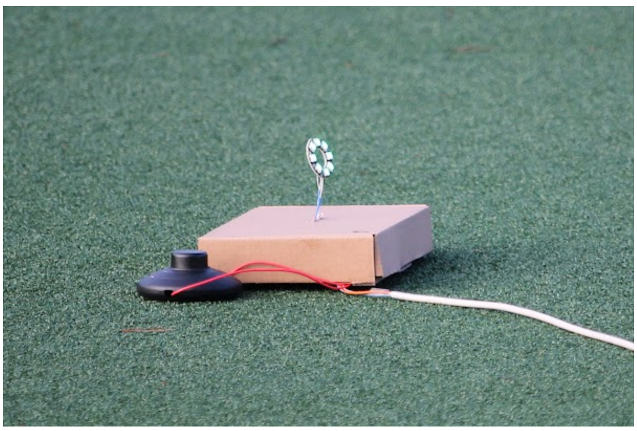

Figure 2: SixFeet LED station

As of now, there is only one gameplay mode available; a two-player high-intensity interval training game. Two players have to run from one LED station to the next based on their respective colour lighting up at the next station. This next station is carefully determined by the smart-allocation algorithm, ensuring that the running paths of the two players do not cross, ensuring that the social distance rule is not breached. A more elaborate explanation of the smart-allocation algorithm is provided later on, in section 3.1.1.1.

The current system is still limited. There are many variables and elements to the existing design and system architecture that could be explored. Only one form of gameplay is supported as of now. However, there is much potential for tailoring the system for sport-specific interactions, for instance, by changing the configuration from circular to another shape, creating more relevant running patterns. Additionally, different gameplay modes could help achieve specific training goals. These are mere examples of how the current system can be tailored for sport-specific interactions.

To this end, this thesis aims to demonstrate the possibilities and sport-specific application potential of the platform SixFeet by developing a suite of games that can be used as effective and meaningful training alternatives in times of corona-induced lockdowns. This thesis focuses on developing sport-specific applications of SixFeet for field hockey to demonstrate this. This thesis aims to create an array of training exercises that each address a different training goal to display the potential of SixFeet fully. Therefore, the main research question that encompasses this goal is as follows.

Main RQ: How can the SixFeet platform be used to facilitate meaningful sport-specific training exercises for field hockey?

To adequately answer this question and to guide answering this question, a few sub-questions are raised.

SQ1: How can meaningful training be defined?
SQ2: What are important (technical) requirements for an interactive sports platform concerning field hockey?

The goal is to create a set of sport-specific exercises for the SixFeet platform that together provide a balanced, meaningful training session for field hockey, with this demonstrating the potential of SixFeet.

3. Background Research

In order to answer what meaningful training is and in order to create meaningful training exercises for SixFeet, knowledge on training methods is necessary. This chapter presents relevant research, existing literature and other solutions to be considered before entering the ideation phase. Additionally, research on how to construct a training and what elements should be prevalent in meaningful training was done.

3.1.State of the Art

The state of the art comprises five different elements. Firstly, the current state of SixFeet and the prototype are described and critically analysed. Secondly, an overview of existing sports-platform products with a similar system architecture to SixFeet. Thirdly, several alternative, corona-safe training methods are analysed and discussed. Next, existing training exercises are considered with or without an interactive sports platform. Lastly, the relevance of an interactive, corona-safe sports platform is explored in the form of a literature review. This review will help identify why and where a system such as SixFeet could provide a service in times of lockdown.

3.1.1.SixFeet: the current system

SixFeet is originally part of a project of the Creative Technology curriculum. It was developed in module 6 by Jonah Sanderman, Babet ten Hagen, Louis van Maurik, Hanneke Goud and Annabelle de Ruiter. As part of this project, an initial prototype was created and limited user testing was performed as a proof of concept. This section outlines the current status and details of the system.

3.1.1.1.System Architecture and Prototype

SixFeet comprises, at the minimum, five LED station nodes. Each node has a tactile foot switch and an RGB LED ring (see Figure 2). Figure 1 shows that the wired nodes are placed in a circular configuration, with all wires coming together in the centre of the playing field, connected to a laptop and an Arduino Uno. The laptop serves as a control mechanism for starting the game. In addition, the computer shows a Processing interface where the game's current status is displayed (see Figure 3). Additionally, the system is equipped with auditory feedback, where players get informed of the current score and status of the game. A more detailed overview of the system architecture can be seen in Figure 4.

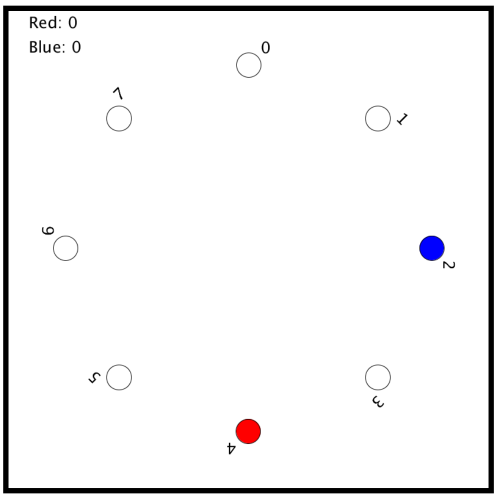

Figure 3: Processing interface SixFeet

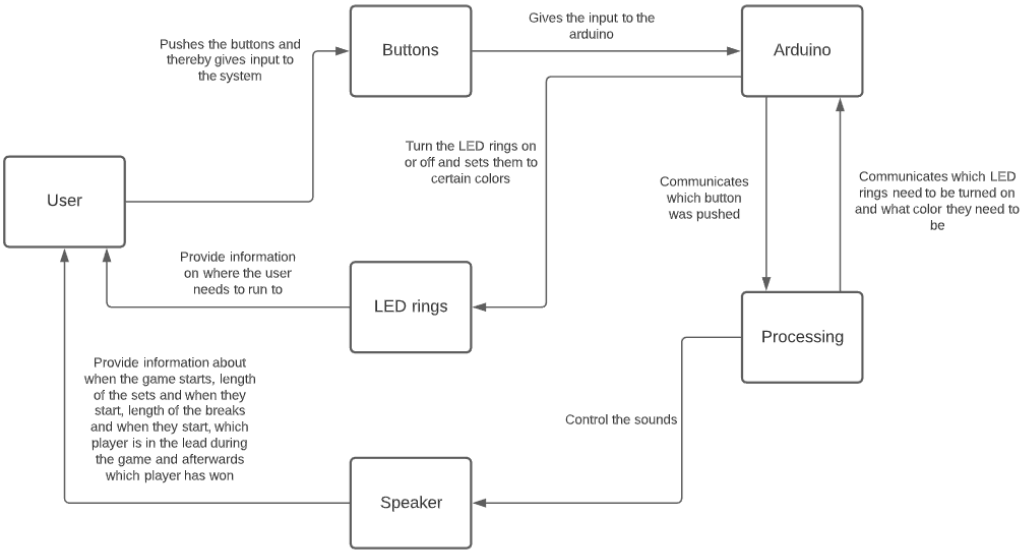

Figure 4: Detailed overview of system architecture of SixFeet

3.1.1.2.Smart-allocation algorithm

A smart-allocation algorithm is deployed to ensure that players do not intersect each other's running lines while playing, compromising the 1.5 metres distance. This algorithm carefully determines the next node based on the other player's location. It is important to note that while this paper addresses the required social distance as 1.5 metres or six feet, SixFeet could also work for other, user-defined distances.

To demonstrate how this algorithm works, take the following example (see Figure 5). In this example, the first player (blue) arrives at node 1, coming from node 6. The second player (red) arrives slightly later at their respective node 4, coming from node 2. As player one was the first to activate their node, player one is the first to get a new node. This new node is assigned based on the path of the other player (red) and the current location of the player (blue). The possible new nodes are contained in a list [1,2,3,4,5,6]. First, the current location of the player, in this case, node 1, is removed from this list, leaving [2,3,4,5,6]. Next, the path of the other player (red) is considered. This path blocks nodes 2, 3 and 4. The algorithm also removes these nodes from the list, leaving [5,6]. From the nodes remaining in the list, the algorithm chooses one option at random. This process is repeated every time a new node is activated.

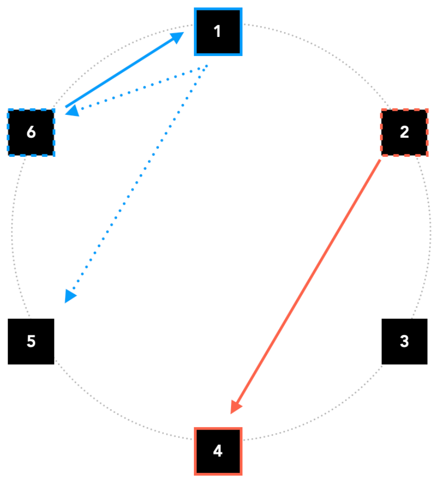

Figure 5: Smart-allocation algorithm SixFeet

A small user study [14] revealed that the smart-allocation algorithm performed as intended. The performance in terms of distance was compared to a random algorithm that decided the next node randomly. The results showed that there was no breach of the social-distancing rule in the game versions with the smart-allocation algorithm. In addition, users were not aware that the smart-allocation algorithm mediated their movements. They did not seem aware that they were keeping 1.5 metres distance, as users mentioned the interaction throughout the game felt close.

3.1.1.3.The game and interaction

As of now, there is only one gameplay mode available; a competitive two-player, high-intensity interval training game. In this game, players are each assigned a colour they have to follow, running from one node to the next based on this respective colour lighting up on one of the nodes. The two players compete, each trying to get as many points as possible. Points are scored for every correctly activated station. The player with the most points will win the game. Additionally, auditory feedback is provided during and after the game to increase the sense of competition.

As the current game is a type of interval training, the game is divided into cycles of activity and rest. The work-to-rest ratio for this game is 2:1. Each active session takes one minute, after which players get a 30-second break. The number of cycles played can be determined beforehand to tailor the training' intensity to the athlete's needs.

3.1.1.4.Discussion and limitations of the current system architecture

The current SixFeet system is still rudimentary and limited in many respects. Firstly, the prototype in its current form is wired, limiting the node-configuration freedom. The nodes can only be placed in the circular configuration, and no additional nodes can be added. In addition, the wires could obstruct athletes while playing, potentially preventing the sports-specific adaptation to sports such as hockey that require a ball to roll over the playing field that the cables would block. Next to that, the wires all come together in the middle of the playing field, where they are connected to a laptop and an Arduino Uno. This seriously limits the moving freedom of players and prevents the use of the system in certain sports-specific scenarios where balls could damage the laptop. Furthermore, the nodes feature foot switches that have not proven very sturdy in earlier user tests. The foot switches also require players to pause in their movement to activate the button. Lastly, the LED light ring on each node is relatively small and could be easily missed or mistaken for different colours in certain light conditions.

In addition to the limitations that the system architecture imposes, there is currently only one game available. This game is not sport-specific and limits the meaningful training possibilities for athletes. It, therefore, is not able to replace a traditional team training session. While the current game demonstrates the functioning of the smart-allocation algorithm, it fails to explore more specific use-cases for different user groups and training goals.

3.1.2.Similar System Architectures

Several systems and sports-platform products have similar hardware features to the SixFeet system. A selection of these systems was made, where the relevant features are put in Table 1 to provide an overview. Additionally, a discussion and analysis of each of these systems is provided.

3.1.2.1.Relevant Design Elements

A few design elements and variables are relevant when considering similar system architectures and the potential corona-safe application for these alternative platforms.

- Activation: How are nodes activated? Is this corona safe?
- Flexibility in the set-up: Can the nodes be freely arranged?
- Maximum number of nodes: what is the maximum number of nodes that can be added to the system?
- Maximum number of colours: How many different colours can the LEDs emit?
- Custom programming: To what extent can users program their exercises, if at all?

The maximum number of nodes and colours together can determine the maximum number of players that can safely play with the smart-allocation algorithm in its current form. As each player gets assigned an individual colour, there should be enough (differentiable) colours to allow multiple players. It should be pointed out that even though some products might feature RGB LEDs with an endless array of colours, the colours have to be quickly differentiable by players, limiting the total perceived different colours and players. Next to this, the number of nodes also impacts the maximum number of players possible. When more nodes can be added to the system, the bigger the playing field can become, allowing more players to participate safely at a distance.

Arguably, all of these systems could be considered programmable, as they could likely easily be programmed by the developers to include the smart-allocation algorithm. However, for this analysis, the programming options for users are considered. Custom programming could not only facilitate the implementation of the smart-allocation algorithm but can also contribute to providing trainers and coaches freedom in designing more tailored training exercises.

It should be noted that other elements such as battery life and wireless range could be of interest as well. However, it was found that these did not form a limiting factor for most systems. Most systems had at least 8 hours of battery life and a wireless range of 40 metres or more. In addition, the control method was mostly via a mobile phone app except for some systems, including a remote next to an app. Lastly, most systems were found to be portable, with the exception of one system.

Table 1: Overview of design features of similar system architecture products

Interactive Sports Platform	Activation	Flexible set-up	Maximum number of stations	Maximum number of colours	Custom programming	Image
SmartGoals [15]	Motion-sensor	Yes	12 (6 portals)	2	No	
FitLight [16]	- Motion sensor - Touch	Yes	32	Endless	Yes, predefined order of stations.	
ReactionX [17]	- Motion sensor - Touch	Yes	12	Endless	No	
Lummic [18]	Touch	Yes	15	Endless	Yes, predefined order of stations.	
BlazePod [19]	Touch	Yes	12	8	Yes, predefined order of stations.	
Yalp Memo [20]	Touch	No	7	N/A	No	

3.1.2.2.SmartGoals

SmartGoals [15] is an interactive training platform developed in Eindhoven. There are different options for field hockey, soccer, fitness and other physical education. The technology is the same for all sports; the base in which the technology rests is interchangeable to accommodate sport-specific qualities. As an example, the hockey set includes weighted bases that can withstand the heavier impact of a hockey ball. The stations feature two coloured LED lights and are activated by motion. Though the stations can be placed freely in any configuration, two stations are needed to form a portal through which the player can walk to activate the stations. The size of these portals is variable. The stations are not programmable to the user and will therefore light up at random. The maximum playing field can include up to 12 stations or six portals.

SmartGoals can be arranged in flexible configurations and have a sport-specific casing to withstand different degrees of impact. However, the games are not dynamically programmable, therefore not allowing the use of the smart-allocation algorithm. Other sport-specific, corona-safe games could possibly be played using SmartGoals, however, these would not let users dynamically use the same playing field as SixFeet does. In addition, SmartGoals are relatively expensive, when compared to the other systems discussed in this section, and might therefore be less accessible to a large audience. Lastly, the number of players is limited by the maximum number of portals. Next to that, there are only two-player colours available, again limiting the maximum number of players, applying the smart-allocation algorithm, to two.

3.1.2.3.FitLight and others

Fitlight [16] is a small and portable interactive training tool. The stations are activated by touch or motion-sensing. FitLight allows for up to 32 stations in one playing field. There is an endless array of LED colours that can be used to accommodate many players. The FitLights also feature an optional beeping sound, unlike most similar systems. The stations are programmable, however, not in real-time. Before starting the exercise, the user has to option to set a pre-defined order of stations to light up, so the stations cannot be dynamically programmed based on real-time events in the game. Additionally, an app is available that offers insight into performance data and can serve as a controller for the FitLights.

There are many similar systems to FitLight, such as ReactionX [17], Lummic [18] and BlazePod [19]. The functionalities and design are very similar and are put side to side in Table 1. Systems such as FitLight offer many functionalities but are limited by the inability to program them dynamically. For some of the systems, custom programming is possible. Users can select whether the next node lights up randomly or in a set order. This order, however, is pre-determined and therefore can not incorporate dynamic changes and accommodate for the smart-allocation algorithm. Most of the systems carry a full array of colours in their LED nodes, thus only limiting the maximum number of players by the maximum number of distinguishable colours and the maximum number of nodes that can be added to the system.

3.1.2.4.Yalp Memo

Yalp Memo [20] is an example of an interactive playground that is permanently installed. The system features seven pillars in a circular configuration, where one pillar is situated in the centre of the playing field. The pillars feature sound, light and a screen. The pillar or stations are activated by touch. There is a large selection of thematic games available, including quiz and trivia games. The stations are not user-programmable despite the large number of games that can be chosen. Due to the permanent nature of the set-up, Yalp Memo installations are usually found in public playgrounds or school areas.

Yalp Memo allows for a large variety of gameplay easily accessible to the public. However, designing sport-specific, meaningful training exercises for this system can be challenging. Firstly, the setup has a pillar in the middle of the playing field, limiting the movement freedom. In addition, this introduces a new challenge for the smart-allocation algorithm as users cannot move in straight lines from one pillar to the next. Secondly, players have to physically touch the pillars to activate them; this introduces the possibility of infection through touch. While some corona-safe games might be possible for this particular system, it does not fit the application for this thesis; meaningful sports-specific training exercises.

3.1.2.5.Discussion and overview

There is an abundance of systems that feature a similar system architecture to SixFeet. Each system with a slightly different configuration of the design elements previously identified. Most of these systems could be suited for implementing the smart-allocation algorithm and could facilitate meaningful training with this algorithm. In regard to the sport-specificity and the impact of balls, SmartGoals is most suited. However, the limiting factor of SmartGoals is the maximum number of colours and number of nodes. This greatly limits the scalability of the system. Systems without motion-sensing activation are also limited with regards to being corona-safe. These systems require touch activation, which arguably could endanger users by opening the risk of infection through surface. Considering this, FitLight seems to be suited the best for implementing the concept of SixFeet. The system can be activated by motion and has a large number of maximum stations and colours. The only limiting factor here is the sturdiness of the stations, as they do not have a weighted base, such as SmartGoals. This could potentially be solved by raising the stations slightly above the ground, preventing impact from balls.

3.1.3. Alternative corona-safe training methods

There are many alternative methods available to still have physical activity that complies with social-distancing measures. These alternatives range from different combinations of online/offline, social/individual and more or less sport-specific. This section provides some examples of alternative training methods and analyses and discusses these.

3.1.3.1. Yalp Workout Cycle 1.5

Yalp Workout Cycle 1.5 [21] was developed as an outdoor sports area where users can individually exercise at a safe distance. The area features six workout areas that each have a different fitness installation, all situated at least 1.5 meters distance from each other (see Figure 6). The six workout areas together create a full-body workout routine, each addressing a different muscle group. As users have to touch the fitness installations in each area, adding a disinfectant spray column is possible to prevent the virus spread through surfaces.

This installation allows players to come together in real-life to exercise in a social setting, however, players do not actively interact with each other since they are not simultaneously exercising the same thing or are dynamically sharing a playing field. In addition, they are at a distance of at least 1.5 metres, thereby limiting the quality of the social interaction. While the installation does provide a full-body workout, it does not train sport-specific or strategical skills, thereby not wholly replacing traditional team sports training sessions.

Figure 6: Yalp Workout Cycle 1.5 [21]

3.1.3.2. Quarantine Camp

Research has been done into the perception and effectiveness of *Quarantine Training Camps [22]*. In these camps, athletes, including coaches, are isolated from the outside world for a few weeks to allow for uninterrupted training without any restrictions. In this case, all the athletes and staff are part of the same 'bubble', making it possible to come into close contact. The research performed a 30-day trial of such a camp. After 30-days, they observed an overall improvement in the athlete's wellbeing, stress and performance.

Although these camps allow for fully-uninterrupted training, they are very demanding on athletes' personal schedules and can be hard to organise. While this may be an option for more professional or elite athletes, it can be more challenging for recreational players. Subsequently, the quality of the social interaction can be questioned. Players can uninterruptedly interact with fellow athletes but simultaneously are entirely isolated from friends and family at this time. In addition, such a camp does not replace a regular training schedule; rather, it changes the schedule to a month-long intensive training period, after which the athletes return to the outside world. Therefore, these camps do not provide a long-term solution.

3.1.3.3.Home-based training

There are several home-based alternatives available that promote physical activity. These alternatives might include digital technologies or communication platforms to integrate social interaction into the experience. Examples could be Youtube follow-along workouts, Zoom fitness sessions, Wii or Xbox Kinect games or offline training using home-fitness devices.

Some of these alternatives can be considered more sport-specific than others, depending on the equipment and space available to the user. Research has shown that mere physical activity is often not enough to combat the effects of detraining, sport-specific stimuli are necessary to avoid long-term detraining effects [11]. For team sports, it can be hard to replicate competition-like situations in at-home alternatives. Additionally, it can be more difficult for players to bring up motivation. A report by the NOC*NSF [9] showed that the biggest reason for the decrease in physical activity, except for the closing of sports clubs, was the lack of being able to sport in a team and the lack of motivation.

3.1.3.4.Discussion

Although there are alternative methods available that still promote physical activity or some form of social interaction during periods of lockdown, these alternatives usually fail to combine meaningful physical activity with social interaction. Team sports that are often dependent on close physical interactions can use any of these alternative training methods, however, the methods fall short in providing training methods that address specific skills that are relevant in competitions, with the exception of the Quarantine camp. However, due to the intense nature of the Quarantine camp is not attainable for everyone and requires a sacrifice in non-sport-related social contact. All in all, each of the systems presented in the past section seems to have a major downside, compromising either the sport-specificity or the accessibility or even the social aspect of the solution.

3.1.4.Existing field hockey training exercises

Hockey exercises are abundant on the internet. Many websites provide full training sessions or individual activities, targeting a specific training goal or outcome. Trainers can use these exercises to curate full training sessions. This section provides an overview of different websites and sources for these training exercises and how these websites categorise their exercises.

3.1.4.1.KNHB

On the official website of the Koninklijke Nederlandse Hockey Bond [23], there is a large and comprehensive section of full training sessions and individual exercises. Notable is that these exercises are all available for free. These exercises can be filtered on desired training outcomes, age categories, duration, space and technical and tactile elements. Every training session or exercise has a detailed explanation and lists the materials needed. Additionally, the website provides tips for trainers, on what to pay special attention to.

The techniques that this website identifies are mainly stick-wielding techniques. How to pass and accept balls in different situations or how to block the ball from opponents. The tactics are differentiated by the situation around the ball. For example, one of the categories is a situation where there are more opponents currently surrounding the ball than players of the home team. The training exercises in these categories train tactics on how to deal with such a situation.

In addition to technical skills, there are also exercises that address tactical skills. These tactical skills are split into a few categories. These categories are distinguished by different match situations. An example is a situation where the ball is surrounded by more opponents than players of one's own team. Combinations of technical and tactical skills can also be used to find exercises on the website.

3.1.4.2.SmartGoals

To provide trainers and coaches with inspiration, the developers of SmartGoals created a number of example training exercises with SmartGoals [24]. These exercises can be found on a separate website that not only has hockey-specific exercises but also features soccer and fitness and physical education exercises. The website defines 7 training categories; Warming Up, Moves & Skills, Fitness, Finishing, Positional Play, Games and Goalkeepers. Every exercise is explained extensively and an exemplary video is provided for each. In addition, the setup of the stations is clearly shown in the 'training card' that not only shows this, but also the number of players and needed equipment. A large part of these exercises are more game-like and require small teams to compete against each other.

3.1.4.3.Other sources

There are a number of other websites available, paid and free, that offer training exercises specific to field hockey. These exercises are often part of the KNHB Academie and fit the proposed Spel & Ontwikkeling (S&SO) training vision [25]. This vision was proposed by the KNHB to provide trainers and coaches with a framework on how to design meaningful training exercises. This framework is discussed more extensively in section 3.2.5. In addition, there are a few books published that trainers and coaches can consult when composing a training session.

Overall, there are a lot of resources with a large variety of different hockey training exercises, with an abundance of training goals and outcomes. These exercises could serve as inspiration in the ideation phase. Additionally, specifically, the exercises developed for SmartGoals could serve as an inspiration on how to integrate a smart sports platform in training sessions.

3.1.5.Literature Review on the relevance of a social interactive sports platform during lockdown

3.1.5.1.Introduction

The general aim of this literature review is to validate the relevance and explore how a system such as SixFeet could be beneficial in times of a pandemic. To do this, there needs to be an understanding of the impact and the effects of COVID-19 on team sports behaviour and the possible shortcomings of not being able to perform sport-specific team training.

The first part of this literature review will explore the overall benefits of (team)sports. The second part will focus on the practical impacts and issues of disrupted sporting and exercise behaviour as inflicted by the pandemic regarding physical well-being. The third part will explore the effects on athletes' mental health. Lastly, by combining these findings, a conclusion is drawn on the relevance of a system such as SixFeet, and recommendations for the development of the system are given.

3.1.5.2.Health benefits of participation in team sports

Participation in team sports can positively influence athletes. These positive influences can be categorised as two positive health outcomes [13]. In the first place, participation in team sports has positive social health outcomes [13], [26]-[29]. Participation in team sports can give athletes a feeling of social connectedness [28] and is essential in maintaining and creating (new) friendships [29]. Eime et al. [26] describe how participation in team sports can be a valuable tool for children to develop critical social skills, such as making friends, communicative skills, and collaborative skills. In another research, Eime et al. [27] explore the health benefits for adults; here, Eime et al. add to the previous study by showing that these social benefits are not limited to children but also occur in adults. From this follows the importance of the social aspect in team sports.

In the second place, team sports can have positive psychological health outcomes. In the second research, Eime et al. [27] establish that psychological health outcomes apply more to adults, as adults have often already developed most of their social skills. Psychological health benefits include stress relief, self-esteem and a feeling of empowerment [13]. Nonetheless, psychological health benefits are also prevalent in children and adolescents [26],[30]. Pluhar et al. [30] observed significantly fewer cases of anxiety and depression among adolescents who participated in team sports as opposed to their peers who did not. All in all, team sport seems to be a powerful tool to prevent and reduce anxiety and depression among athletes.

Overall, participation in team sports positively influences the mental health of both young and older athletes. In children, participation in team sports can be a vital part of developing crucial social skills. The lack of access to team sports training could prevent the development of these skills in children and could negatively influence the overall well-being of adults.

3.1.5.3.Issues in training inflicted by the pandemic

There are multiple adverse effects and issues resulting from the forced change in (team)sports behaviour due to the COVID-19 pandemic. Firstly, athletes are physically impacted in the form of 'detraining effects' due to COVID-19 restrictions preventing team training sessions. Mujika and Padilla [31, p.79] define detraining as "the partial or complete loss of training-induced adaptations, in response to an insufficient training stimulus". A study by Heo, Park and Jee [7] show the presence of this phenomenon in a study that revealed a significant decrease in physical fitness in declined muscle mass and increased fat percentages after a period of lockdown. Girardi et al. [6] name several physical capacities that are negatively influenced by the inability to train, such as endurance, strength and flexibility. While endurance and strength are capacities that can arguably still be trained alternatively, Friebe et al. [11] make clear that the deficiency in sport-specific activities could cause quick deterioration in athletes' performance. This sentiment is repeated in the research results by Dauty, Menu and Fouasson-Chailloux [12], who show significant detraining effects and loss of performance in young elite soccer players who had access to alternative home exercises. While this study only considers detraining effects in young elite players, other research shows that other athlete groups are impacted by the phenomenon of detraining as well. A study in Turkey showed similar detraining effects in amateur adult soccer players [5]. From this, it should be noted that detraining effects are prevalent during periods of lockdown in different types of athletes and cannot be avoided entirely by alternative, non-sport-specific training methods.

As a result of the prolonged cessation of training, serious detraining effects could render athletes more vulnerable to injuries once returning to regular training routines. Jukic et al. [4] add to this by warning athletes about the increased risk of injury returning to normalcy. The deficiency in training can lead to reduced flexibility, which in turn can lead to incorrect posture, resulting in injury [7]. Moreover, athletes have to be wary of overtraining [32]. A system that would allow athletes to safely train sport-specific elements in addition to endurance and strength exercises could prove to be beneficial to prevent overtraining and possible injuries.

In addition to athletes losing performance and being more vulnerable to injuries, the often lack of guidance and correct equipment for training alternatives can have a negative impact on training effectiveness. Stowers and Fernández [33] conclude that athletes training on-site with the presence of a coach were quicker to gain muscle mass than their peers who trained remotely with no guidance present. Jukic et al. [4] suggest it can be challenging for athletes to ensure the right levels of training; Jukic et al. [4] point out that this is especially true for elite athletes who require precise exercise prescriptions. However, Sanderson and Brown [34] maintain that this issue is also relevant and present in amateur athletes by pointing out that there are no guarantees that amateur athletes are following or completing at-home training alternatives correctly. Supervision and coaching seem to be essential elements in the efficacy and quality of training.

Lastly, a suitable space and the right equipment are not always readily available. Sanderson and Brown [34] point out that there is a multifaceted financial issue resulting from the pandemic. On the one hand, people have often lost (part) of their income, resulting in less monetary funds available for secondary needs such as sports. Simultaneously, investment is mostly required to have (sport-specific) training alternatives at home. Mutz [2] adds to this by concluding that the pandemic might create new inequalities and amplify the already present inequalities. In addition, the lack of sponsors and sports scholarships impacts a lot of athletes' ability to participate in sports [34]. Financial issues and imbalances could influence how well athletes train and make sports less accessible to some groups.

Overall, the preventative measures against COVID-19 limit athletes in crucial ways. Although some of the aforementioned issues could be overcome with the help of at-home training alternatives and online communication platforms, they do not seem to cover the load fully. These alternatives are not always able to adequately address the issues.

3.1.5.4.Mental health

As a result of the lack of constructive support and meaningful training possibilities due to anti-COVID-19 measures, many athletes experience some form of mental health issues during lockdown periods. A 2016 study showed that athletes experiencing difficult situations, such as disappointing performances or injuries, could be at higher risk of mental problems [32]. Peña et al. [3] suggest that this situation is anomalous to COVID-19 induced lockdowns. Mutz [2] demonstrates that the negative effects on mental health are perceived around two times as high when they result from external constraints, such as a forced quarantine than from voluntary choice of not training. Similarly, a French study found athletes to experience high scores of anxiety leading up to the return to the sport due to the lack of (meaningful) training they had during the lockdown [35]. All in all, lockdowns and the inability to train take a toll on the mental health of athletes, which is often already partly compromised by other hardships that the COVID-19 crisis brings.

3.1.5.5.Conclusion and Discussion

This literature review aimed to gain insights into the effects of the pandemic on sports behaviour and, in turn, the impact of the forced change to sports behaviour on athletes' overall well-being. The health outcomes of team sports were also explored.

The pandemic has put athletes in a vicious circle of adverse effects where cause and effect seem to be entangled. Changes in mental and physiological well-being are interdependent and might directly or indirectly influence each other or amplify other issues. While maintaining physical exercise levels is an effective way to deal with the adverse effects imposed by confinement, the possibilities to do this do not always prove fully adequate in breaking the vicious cycle. A system that would allow athletes to train sport-specific skills in a social context with the optional presence of a coach could positively influence athletes' overall mental and physical well-being and break the vicious cycle. A system as such could also prevent possible injuries and minimise the backlog returning from a period of quarantine.

Due to the ongoing nature of the COIVD-19 pandemic, the sources reviewed are limited by the knowledge and insights available at the time of writing. New insights and longitudinal study results could provide a more complete view of the issues of the pandemic to athletes and how a system such as SixFeet could address these issues.

3.1.6.Conclusion and Discussion

This state of the art presents many systems similar to the system architecture in question; SixFeet. Placing a motion sensor and an LED light on a node is not something novel. Using these system architectures to create sport-specific, meaningful training opportunities, however, is something novel. This stipulates once more that this Graduation Project is not so much about the prototype and system architecture of SixFeet, but rather about the application. This application could then potentially even be applied to existing systems.

Additionally, while there are several other options available that stimulate physical activity during periods of quarantine, these options often fail at a sport-specific level. Simultaneously, the relevance of representative, meaningful exercises is re-iterated in the literature review.
While for some users, physical activity in itself might be enough, for higher-level athletes training certain skills is crucial.

Lastly, existing training exercises can serve as a source of inspiration for creating a diverse set of training exercises and can help inspire how to integrate a smart sports platform in training. The wide range of categories and training goals can be a starting point for the ideation phase.

3.2.Training

To develop meaningful training exercises, knowledge about different types of training methods and training stages is needed. This section will first explore field hockey. Next and identify a categorisation of training exercises and methods. Next, the different stages athletes go through when developing sports skills are explored. Lastly, is a section about a proposed method of developing a full training schedule for field hockey.

3.2.1.Hockey

In order to design sport-specific training exercises, it is essential to identify the sport that these exercises are going to be developed for. This section starts with a definition of hockey and follows with a rationale of choice for hockey in this thesis.

3.2.1.1.Field hockey in general

There are several types of hockey, but this thesis focuses specifically on field hockey. Like many other team sports, field hockey can best be defined as an invasion sport, where players dynamically share the same playing area as their opponents [36]. "Invasion games typically refer to complex and dynamic activities involving two teams who compete for one object, usually a ball, in order to advance the object into the opponents' territorial playing area in order to score a goal/points." [37, p.14].

Field hockey is characterised by playing with a stick and a small, hard ball. Teams exist of 11 players each and in matches of 70 minutes, divided into quarters of 17,5 minutes each. The goal is to score as many points by placing the ball in the opponent's goal while minimising the opponent's score. It is important to note that balls can only be touched by the stick and not by players' feet. In case of contact with the ball by foot in the opponent's goal area, players are allowed a (penalty) corner. In addition, it is only allowed to touch the ball with the flat side of the stick and not the outer, convex side. Lastly, the ball is pushed over the ground and not through the air. While it is not uncommon for the ball to lift off the floor slightly, hockey is played over the ground. [38]

Field hockey is typically played on synthetic turf fields. The ball is not allowed to go outside the outer lines of the playing field. If this happens, the team responsible for this has to forfeit the ball to the opponent, who can pass it back into the field from where it left. Additionally, the field is divided into four parts, with the outer parts on either side being the goal areas. According to the place where the ball leaves the field, there might be a variation in the protocol of returning the ball into the field. [38]

Similar to many other team sports, there are different positions players can play in hockey. Each position comes with different roles during the game and requires specific skills [39]. The exact positions and line-up can differ per team and coach, but generally, the following positions are prevalent in most hockey teams. Firstly, there are goalkeepers. They are typically dressed in protective gear to prevent injury from the ball's impact. Secondly, after the goalkeeper, there generally are defending players. These players are often assigned a side of the field; left, right or centre. The main objective for these players is to prevent the ball from entering the goal area and subsequently get the ball out of their goal area. In case of a confident attack on the opponent by their team, they sometimes can help out in the front of the playing field. These players have to have solid defending tactics [39]. Thirdly, there is often a line of centre players after the defending players. Depending on what is happening in the game, these players can help with the attack or defence. These players often have to run a lot, making endurance and anaerobic power a vital training element [39]. Lastly, at the front are the attacking players. The main objective of these players is to get the ball to the opponent's goal area and try to score. These players have to try and pass defending, and centre players of the opponent's team and therefore should have strong passing skills and tactics [38].

3.2.1.2.Rationale Hockey

As this thesis aims to demonstrate the sport-specific potential of SixFeet for team sports, choosing a representative sport to do so is important. Like many team sports, (field) hockey belongs to invasion sports, making it a good representation of team sports. The outcome of this thesis can then easily be adapted to suit other invasion team sports or serve as an outline on how to develop team sport training exercises for invasion sports. This refers to the principle of extensibility, described in Chapter 3. In addition, hockey provides an added challenge and dynamic of playing with a stick.

3.2.2.Technical versus tactical

There are many frameworks and proposed categorisations for training exercises and desired training outcomes. These categorisations can help determine what different training elements should be present in the suite of exercises developed for this graduation project. Additionally, categorising training types can help pinpoint what categories suffer most from social-distancing measures. A categorisation or distinction can be made in the form of technical versus tactical skills.

Firstly, technical skills include basic skills such as passing and moving with the ball to slightly more advanced skills such as goal shooting [40]. In the case of hockey, this includes mastering handling a stick. In order to be successful in competition, it is important to master these technical skills. These technical skills are therefore usually developed before partaking in competition [41]. Technical skills are traditionally and often trained by repetitive exercises, while research shows that variations in exercises can be beneficial [42]. In some cases, other physically strengthening exercises can be part of training technical skills [40].

Secondly, sports skills can be distinguished as tactical. Tactical skills can be defined as skills that help make choices and decisions in games [43],[44]. Tactical skills are a combination of subconscious and deliberate processes [45]. They are an important part of competition as athletes learn how to respond to game dynamics with the applicable technical skills [43]. In the case of hockey, tactical skills could include knowing when or to whom to pass a ball.

Research by Memmert and Harvey [46] defines six validated, non-specific training tasks that can be used universally for training tactical skills in invasion sports. These tasks are prevalent in the majority of invasion spurts, including field hockey. The six goals are; attacking the goal, taking ball near goal, playing together, identification of gaps, feinting and achieving an advantage through supporting, orienting and coopering with partners.

Training technical skills, such as ball passing techniques, using repetitive drills is arguably still possible at a distance. Especially since the ball is not directly touched by players, but rather by their stick, even allowing for corona-safe passing of the ball. Training tactical skills, however, can be more of a challenge. Tactical skills involve rapid-decision making and reacting to the dynamics of the game. Training this at a distance can be hard, as this is far from being close to a competition-like situation.

3.2.3.Game-Based Training Approach and Small-Sided Games

Other more sport-specific approaches to effectively train technical and tactical skills are Game-Based training or Small-Sided Games. These approaches are increasingly used by coaches and trainers to simultaneously improve skills and physiological form [47]. Game-based training is used to replicate the physiological and technical demands of competition to improve rapid decision making and overall athlete performance [47]. Game-based approaches aim to bridge the gap between technical and tactical skills, which is often present in 'traditional' approaches [48]. The technical skills are trained in the context of the game, consequently training the tactical skills of applying these technical skills.

There is little research supporting an increase in technical skills performance in athletes as a result from Game-Based training approaches [48]. However, there is much support for the benefits on the development of tactical skills and decision-making. In addition, research showed that coaches and trainers often have difficulty composing good game-based training exercises [48].

A version of a Game-based training approach is Small-Sided Games (SSGs). "Small-sided games are often employed by coaches based on the premise that the greatest training benefits occur when training simulates the specific movement patterns and physiological demands of the sport." [49, p.3594]. The main difference between 'traditional' approaches and SSGs is the execution of the trained skills in a similar way they occur in competition as opposed to an isolated situation [50]. Typically, SSGs are smaller versions of the true game, with modified rules or changes in the number of players or pitch size. Due to the lower number of players or the smaller pitch size, there is an increase in the ball contact moments per player. This leads to an increased number of technical actions per player [51]. Research found many physiological benefits and a more evident positive effect on technical and tactical skills compared to 'traditional' training approaches [50].

3.2.4.The Development of Sport Skills

To design meaningful training, one should take note of the individual players and athletes. Many models are addressing the development of sports skills. The following model [52] is based on long-term athlete development, where sports are classified as early specialisation or late specialisation sports. Team sports, including hockey, follow a six-stage model of late specialisation. In the earlier stages, the emphasis of training lies on developing general motor and technical-tactical skills. It should be noted that the following model is designed for team sports and other late specialisation sports in general and not specifically for hockey.

3.2.4.1.Stage 1 - FUNdamental Stage

This stage usually takes place at the age of 6-9 years. The main objective of the first state is for players to gain Fundamental Motor Skills (FMS). In this particular stage, sport-specific skills are not yet introduced. Fundamental Motor Skills "include locomotor (e.g. running and hopping), manipulative or object control (e.g. catching and throwing) and stability (e.g. balancing and twisting) skills." [53, p. 1019]. These are considered the building blocks for sport-specific training in a later stage. In addition to FMS, this phase should include an introduction to basic ethics and rules of sports [52].

It is crucial to make this particular stage fun and engaging. In this specific age group, players' attention span is still short, so the activities in this period should be engaging to keep players involved and interested [54]. Purcell [54] suggests short instruction times and minimal competition. Strict rules and pressure can take the fun element out of sports in children. Not having fun is one of the main reasons children drop out of sports [55]. Overall, training in this stage should not be too rigorous and should not include sport-specific skill training just yet.

3.2.4.2.Stage 2 - The learning to train stage

The following stage takes place right after the previous stage, starting at nine years old to about 12 years old in the later stages of childhood. This stage continues developing Fundamental Motor Skills but shifts the attention to developing these skills in a more sports-oriented setting [52]. Overall, technical sports skills are developed in this stage that later forms the basis of athletic development.

This stage can include some limited sport-specific skill training, but children are recommended to participate in multiple sports to avoid early specialisation in team sports [55]. In addition, by encouraging participation in multiple sports, children can discover and voice their preference for which sport to participate in at a later stage. Balyi [52] suggests a 70:30 training to competition ratio.

3.2.4.3.Stage 3 - The Training to Train Stage

The following stage shifts the focus to translating the previously acquired FMS and overall sports skills to tactical sport-specific skills [52]. This stage typically occurs in early adolescence, from 12 to 16 years old. During this time, players experience a growth spurt with significant increases in muscle mass and strength [54]. However, this growth spurt simultaneously causes a short but temporary decrease in flexibility and coordination. Therefore, flexibility training is emphasised during this stage, depending on the level of physical maturity of the athletes [52].

The suggested training to competition ratio is 60:40 for this stage [52]. Too much competition would compromise valuable training time. At the same time, too little competition would prevent athletes from learning how to deal with physical and mental challenges related to competition. An over-emphasis on either is why many athletes do not reach their full potential later in their sports careers [56].

3.2.4.4.Stage 4 - The Training to Compete Stage

Athletes in the fourth stage typically reach late adolescence, from 16 to about 18 years old. This phase starts after the goals of the previous stage, the training to train stage, have been met. The primary purpose of this stage is to optimise the overall performance and develop position-specific skills. The advice training to competition ratio is now set to 50:50 [52]. The general sport-specific training skills are refined now under various specific and competitive conditions. In this stage, tailored training programs are more critical to better meet the individual needs of athletes [54].

3.2.4.5.Stage 5 - The Training to Win Stage

This second to last stage begins as the athlete enters adulthood. In all previous stages, the athlete gathered the necessary technical skills to enter this stage. This stage focuses on maximising the tactical performance of these skills [52]. There is an emphasis on the competition during this stage with a 25:75 training to competition ratio [52]. It should be noted that the competition percentage here also includes competition-specific training activities. These competition-specific training activities include training skills prevalent in competition and typically mimic competition dynamics closely, such as in SSGs [51].

During this phase, a division usually is created. Some athletes go on to pursue their sport professionally or on a high level, while for other athletes, the sport becomes a recreational activity. [52],[54].

3.2.4.6.Stage 6 - The Retirement / Retention stage

This last stage refers to the period an athlete permanently retires from competition. This phase is primarily relevant for professional and elite athletes. The objective of this phase is for ex-athletes to transition into new roles such as trainers or coaches, taking their own experiences with them. This could also be true for amateur athletes becoming coaches of their children's teams. [54].

This model follows the notion that technical and fundamental motor skills are acquired before tactical skills are developed. The technical skills form the foundation on which tactical gameplay rests. From late childhood to early adolescence, there is a switch to more tactical-oriented exercises to prepare for competition.

3.2.5.Designing a Hockey Training

The Koninklijke Nederlandse Hockey Bond (KNHB) [25] proposed a strategy outline for coaches and trainers on how to design a training session.

The first step is to analyse the starting position of the team. Essential elements to consider are the level of the players. Are the players more goal-oriented, or is training more of a recreational activity? Is there a variation in level within the team? Additionally, it is important to consider the current fitness level of athletes. Are the athletes recovering from an injury or a match? The KNHB states that the ultimate goal of successful training is for everyone on the team to be able to participate in the activity.

The second step is to determine the session's desired training outcomes and training goals. To determine these training goals, the KNHB proposes the following scheme (Figure 7). This scheme is divided into four quadrants. The upper two quadrants are relevant when the team is in current possession of the ball. The lower two quadrants are applicable when the opponent is in control of the ball. The training goal should be chosen to reflect developments in previous games and should train to improve deficiencies in these games. The KNHB iterates that it is essential to choose small goals that are achievable within the training session.

The third step is to choose a way to train the goal determined in step two. The preferred training method is similar to the situation in the game, like a small-sided game. In addition, the exercise should integrate multiple choice moments or tactical skills. To address technical skills, a trainer could for example choose to constrain players to a certain passing technique.

The fourth and last step is the evaluation after the training session. This can be achieved by comparing and observing game results. If this evaluation is positive, the next training session could focus on another tactical (or technical) skill. Otherwise, the next training session might address the same training goal, however, with a different exercise.

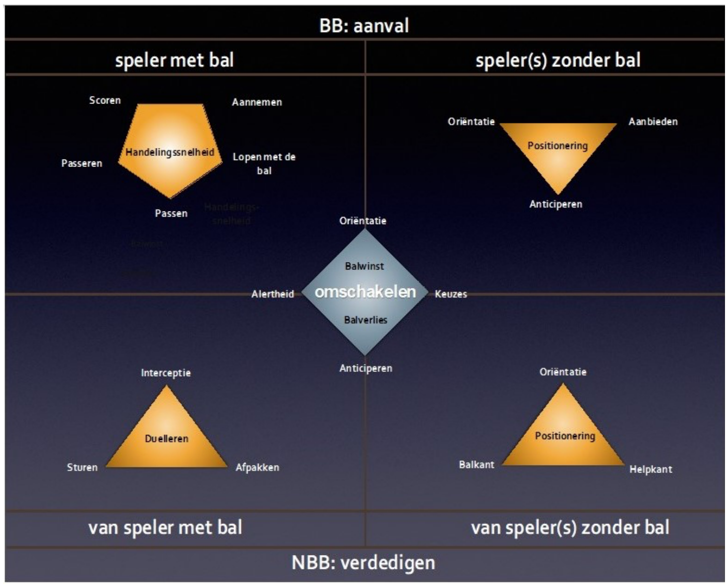

Figure 7: Scheme of training goals KNHB [57]

3.3. Conclusion and Discussion of Background Research

This background research provided an overview of the State of the Art, with relevant technologies and training methods and a literature review on the relevance of a corona-safe, sports platform. The second part of the background research provided insights into field hockey and training methods for invasion sports and field hockey. The main conclusions from the background research can be summarised as follows.

Firstly, there are many similar system architectures to SixFeet, some being more suited for the implementation of a smart-allocation algorithm than others. This shows that the system architecture is not the novel element of this Graduation Project, but rather the use case of the system architecture and the sport-specific application is the main focus of this Graduation Project. While there are other corona-safe sports alternatives available, these options often lack either the sport-specificity or the social interactive element. The literature review revealed that both these elements are essential and accompany many health benefits, both social and physiological.

Secondly, field hockey can best be described as an invasion sport, as can many other team sports such as football or basketball. The rationale for hockey is, because of that reason, that the outcome of this Graduation Project could easily be adapted or replicated to fit other invasion sports. Hockey skills can be categorised as either technical or tactical skills. Tactical skills are impacted by the inability to come into close contact the most, and should therefore be the focus of this Graduation Project. Non-specific tactical skills for invasion sports could be considered to create a more universal outcome of this thesis that could easily be adapted to fit more invasion sports.

Thirdly, tactical skills can be effectively trained using game-based learning and small-sided games. These SSGs aim to combine technical skills with tactical skills by employing technical skills in competition-like situations. This requires fast-decision making and observing. Tactical skills are typically developed after the basic technical skills are formed. In the first few phases of developing sports skills, the focus lies on developing fundamental motor skills. Going through the phases, the focus shifts from more technical skills to developing tactical skills.

Lastly, a model proposed by the KNHB on composing effective training sessions, suggests that training should be composed according to events in competitions and should start off with a clear and achievable training goal. This training goal can then be achieved through small-sided games and tactical skill training exercises.

4. Methodology

This chapter outlines the approach to developing SixFeet and developing a suite of games for SixFeet to showcase the platform's potential. There is a two-fold nature to this Graduation project; Firstly, there is the system architecture. This is the prototype and underlying technology of SixFeet. Secondly, there is the functional application of the system. This is the concept of meaningful training exercises at a distance.

The system architecture is, in this case, subordinate to designing its application. The system architecture is merely the platform on which the concept of the smart-allocation algorithm combined with meaningful, sport-specific training is demonstrated. Relevant, similar system architectures as identified in the State of the Art are already developed in a way that is beyond the scope of this project. Therefore, the primary outcome of this graduation project is a concept of how these systems can be used to accommodate meaningful, sport-specific training in times of corona using the smart-allocation algorithm. Nonetheless, a prototype that allows for this meaningful exercise is necessary to develop and showcase this concept.

Both elements, the system architecture and its functional application, have a similar design approach that goes hand in hand. This approach is outlined in the following sections. Additionally, an overview of how both elements are evaluated is provided at the end of this chapter.

4.1. Creative Technology Design Process

The backbone of the methodology stems from the Creative Technology Design Process [58]. The Creative Technology Design Process is an iterative design process commonly used in projects throughout the Creative Technology curriculum. This design process exists out of four distinct phases. Each phase has a starting point and an (intermediate) outcome that is continued into the next phase. There are four main phases; ideation, specification, realisation and evaluation (see Figure 8). It is important to note that this design process is iterative, and the phases do not always strictly follow each other. In some cases, phases might occur simultaneously or the design might go back and forth between phases.

4.2. Research through Design

The Creative Technology Design Process is enriched with Research through Design principles. "Research through Design (RtD) is an approach to conducting scholarly research that employs the methods, practices, and processes of design practice with the intention of generating new knowledge." [59, p.167]. In a research through design project, design researchers are trying to find a solution to a 'wicked' problem [60]. Research through Design enables users to engage and interact in ways that were previously not possible. These interactions become observable through design [61]. Zimmerman, Forlizzi and Evenson [60] state that research through design attempts to combine theoretical knowledge with practical, technical opportunities and knowledge. The main objective of RtD projects is not necessarily to create a marketable or commercially viable product, but rather to produce valuable knowledge [60].

In the case of SixFeet, the wicked problem is designing meaningful yet corona-safe training exercises. The theoretical knowledge about training methods is combined with the technical opportunity of SixFeet and the smart-allocation algorithm.

Zimmerman, Forlizi and Evenson [60] suggest four criteria for evaluating contributions that employ a research through design approach. Firstly the process. While it is not expected that the reproduction of the process will yield the exact same results, the process should be described meticulously so that it could be reproduced. Additionally, it is important to provide reasoning behind design choices or choices for deploying certain methods in the design process. Secondly, the quality of the contribution is measured by the invention. The invention must be of significance and should demonstrate a novel integration of ideas and technical opportunities. Through background research it should be made clear how the work add to the current state of art. Thirdly, the relevance is part of the evaluation. A detailed motivation for the contribution, the current state of the art and the preferred state should be reported on to adequately establish the relevance of the contribution. These elements demonstrate how the contribution can potentially make an impact on society. Lastly, a successful contribution should be extensible. This means that there is a possibility to build on, or extend, the outcomes of the contribution. This should be possible by following the process or by using the knowledge that came out of the contribution.

4.3.Co-Design

For the specification and realisation phase, a co-design approach is taken. Co-design is a method where stakeholders and end-users are actively involved in the design and development of the product or system [62]. In a co-designing project, people, often stakeholders, without an engineering or designing background are collaborating in the design process. This is in contrast to the classical, user-centred design approach. In Co-design, instead of merely observing the user in the design process, the user becomes actively involved in the design process.

A co-design approach for developing training sessions can be useful to quickly iterate and make changes in the exercises by user-testing. Additionally, trainers and coaches can give useful insights into the needs of different athletes, as well as into their own preferences. Important is to be wary of not having a single-minded view, as different trainers might have different preferences and views on training.

4.4.Phases

In the coming section, the phases according to the Creative Technology Design Process are outlined. Each phase is enriched by the previously defined Research through Design and Co-design approaches. For each phase, a more specific outline for this Graduation Project is provided.

4.4.1.Ideation Phase

The first phase is the ideation phase. The starting point is typically a product idea or creative inspiration. In the ideation phase, the problem is defined, and relevant research is conducted to shape the idea further. In addition to background research, related work or products can also serve as a source of inspiration in this phase. In this phase, evaluating early ideas and prototypes with clients or end-users can also help define the problem and reveal requirements for the end product. The result of the ideation phase is typically a more defined and complete project idea. In addition, ideas on the user experience and interaction methods can be outcomes of this phase. [58]

In the case of SixFeet, technology is the starting point of the ideation phase. "The process that starts with technology is called tinkering and has as goal to identify novel applications for existing or new technology. "[58, p.4]. This is precisely what this graduation project aims to achieve; identifying and demonstrating novel applications for the SixFeet platform. The existing technology, in this case, is the principle of SixFeet. However, the system architecture is part of the ideation phase as well. The system architecture should not impose limitations on exploring the application and goal of this graduation project. Therefore, considerations about how the prototype can fulfil its role as a mediating platform for the corona-safe training exercises should be considered in this phase too.

In this phase, relevant stakeholders are identified. Representative members of each of these stakeholder groups will be interviewed in an unstructured and informal setting to gain some preliminary insights into the needs and wishes of these stakeholders. In addition, training sessions are observed to get a grip on important dynamics and elements in hockey training sessions. Lastly, an initial list of requirements from the background research, interviews and observations is created. This list of requirements serves as input for the initial concept that is specified more in the next phase.

4.4.2.Specification Phase

The second phase is the specification phase. This phase is used to explore the design space. Typically, a set of prototypes or concepts are evaluated in a short feedback loop. User experience may dictate the functionality and lead to new prototype iterations. The prototypes used are not full-fledged versions of the final product but rather only feature elements of the final solution responsible for parts of the final solution. The result of the specification phase is a set of early prototypes, a specification for the product and the interaction and experience with the product. [58]

Regarding this graduation project, the main ‘prototype’ is the exercises developed for SixFeet. Through co-design, training exercise requirements and concepts are developed in this phase. The active participants in the co-design approach are trainers as well as athletes. In addition to the application of the system, a specification for the system architecture is created in this phase as well.

4.4.3.Realisation Phase

With the product specification resulting from the previous phase, the next phase is the realisation phase. In this phase, the elements and requirements previously defined are combined by realising the product. Practical elements such as components are put together to create a more formal prototype. That is subsequently the outcome of this phase; more advanced prototype(s). Additionally, this phase often features some functional testing and evaluation. [58]

In this phase, the system architecture and its application come together. A suite of training exercises is developed through an iterative process of user testing with the system and making changes to the training exercises. This phase is once again guided by a co-design approach, where athletes and trainers are at the centre.

4.4.4.Evaluation Phase

The fourth and last phase is the evaluation phase. Even though functional testing is often part of the realisation phase, it is also prevalent in this phase. Additionally, original requirements that were defined in the earlier phases are evaluated. Often these requirements are assessed through user testing. The final solution can be positioned using the existing related work identified in the ideation phase. Finally, this phase offers room for personal reflection. [58]

The evaluation is split into two categories; the technical evaluation and the functional evaluation. Firstly the technical evaluation is primarily focused on the system architecture and the smart-allocation algorithm. As the system architecture is not the central focus of this graduation project, this part of the evaluation is limited in comparison to the functional evaluation.

4.4.5.Technical evaluation

In earlier pilot testing, participants did not come into close contact. The smart-allocation algorithm proved to function correctly when compared to a random configuration where the next LED station was decided by chance. However, it is interesting to validate this claim once more with the sport-specific application. Do the dynamics of field hockey and using a hockey stick perhaps change the running lines or do different gameplay modes or node configurations impact the effectiveness of the smart-allocation algorithm?

To check this, a similar approach can be taken as in the pilot test. A drone will hover over the playing field, making sure that all LED stations are in frame. In addition to the players and LED stations being in frame, a measuring tape at 1.5 metres is also laid in the frame. In post-processing of this footage, the measuring tape can be taken as a reference and the footage can be checked frame by frame for any breaches of the 1.5 metres rule. Instances in which players come into close contact will be counted by duration and number of occurrences.

4.4.6.Functional evaluation

Secondly, The functional evaluation will evaluate the final solution to this Graduation Project; the training exercises developed as a demonstration of the sport-specific, corona-safe, potential of SixFeet. This evaluation follows the criteria set from Zimmerman, Forlizzi and Evenson [60] on Research through Design projects, and aims to answer the research question. In addition, the outcome is compared to static, corona-safe exercises and to training regimens during the pandemic. Additionally, through interviews and questionnaires, with both athletes and trainers, after user-tests, an evaluation on the enjoyability and perceived effectiveness can be made.

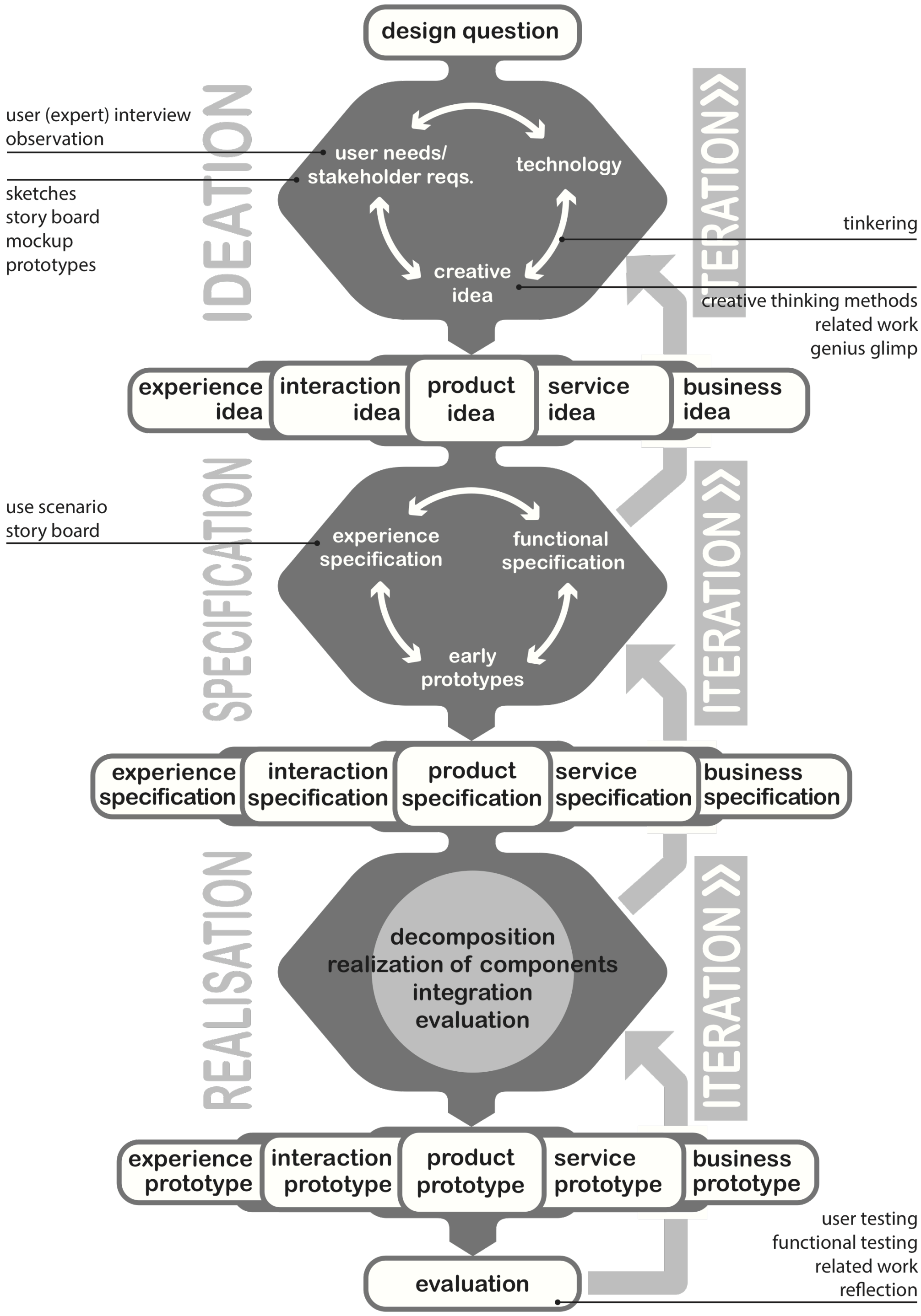

Figure 8: Creative Technology Design Process [58]

5. Ideation

In this chapter, an overview of the ideation phase, as defined in Chapter 3, will be provided. Firstly, the stakeholders, at a high level, will be identified. Next, the main findings of interviews and conversations with representatives of each stakeholder group will be given. Next, the results of the observations of two training sessions will be presented. Lastly, together with the information from Section 3, a preliminary list of requirements for the system will be made, resulting in a first concept and outline as input for the next phase.

It should be noted that at the time of these interviews and observations, there were no covid-restrictions in place.

5.1.Stakeholders

As the system, and especially its application, is explored in a co-design approach, it is essential to identify the stakeholders. These stakeholders can each contribute to the requirements of the final system by voicing their specific user needs.

5.1.1.Athletes

SixFeet aims to train athletes, making athletes critical stakeholders in designing the system architecture and application of SixFeet. Athletes, both amateur and professional, have an interest in meaningful training opportunities during a lockdown. Athletes are the end-users of the system. The exercises and training methods deployed on the platform should therefore be tailored to create the most meaningful and effective experience for these users.

5.1.2.Coaches / Trainers

SixFeet is a tool that coaches and trainers can use. Ultimately, the trainer or coach designs and composes the training session. The coaches and trainers have an overview of their athletes and their individual needs. Trainers and coaches aim to increase athlete performance. Therefore, coaches and trainers have a lot of influence on how the system is used and what should potentially be possible with the system.

5.1.3.Sport clubs

Lastly, an important stakeholder is the sports clubs. They facilitate the training equipment. It is therefore important to prove the value of SixFeet to sports clubs. Additionally, sports clubs will be associated with SixFeet, potentially giving them a positive benefit over other sporting clubs that do not have a system such as SixFeet.

5.2.Stakeholder interviews

To get an informed view of the different perspectives of stakeholders, non-structured, informal interviews were held with a representative from each identified stakeholder group. These interviews are used as a basis for determining the first set of requirements and to gather more insights into the needs and specifics of field hockey.

5.2.1.Amateur recreational athletes

In an informal open conversation with a few female recreational field hockey players of HC HOCO in Oisterwijk, a few initial thoughts and requirements surfaced. The athletes seemed to have less focus on the effectiveness of the training, but rather focused on the enjoyability of the training. Firstly, some players indicated a preference for game-based training exercises or small-sided games. One player said she found these exercises to be more representative of skills necessary in competition and consequently more useful. Another player responded that small-sided games were more engaging and more fun.

Secondly, players indicated to have a preference for varied training sessions, with a collection of short and varied training exercises. Even if some exercises have the same training goal, having a variety of exercises is perceived as more fun.

5.2.2.Coach/Trainer recreational team

In a conversation with the trainer of the recreational team in Oisterwijk, it became clear that players are often at very different levels or in need of different training. This can make it challenging to create a training session that is of use to the entire team. Often, the trainer opts for small-sided games where the trainer assigns each of the players a specific task to take in mind when playing, or the trainer divides the group into sub-groups each with a different training goal.

Not only the form or level of the players creates distinctions within the team, but also the position of that player. Some training goals apply more to a certain type of player. Therefore, from a trainer's perspective, it would be nice to have training exercises that can include different training goals for different participants of that exercise.

5.2.3.Hockey consultant

In addition to traditional stakeholders, an unstructured interview with Wil Hoebergen, a consultant for the Belgian and Dutch national teams and pioneer in field hockey innovation, was held. There are many types of trainers as well as athletes. Each has their own preferred method of training. A system should be versatile to appeal to many of them. The suite of exercises should be diverse so that trainers can mix and match according to their athletes and preferred training styles. On the one hand, it is important to repeat exercises often, but on the other hand, this is often quite boring for the athletes. The ability to combine the traditional, ‘boring’ exercises, with more gamified exercises would add great value to SixFeet.

5.3.Observations training sessions

Two training sessions were observed to gain some preliminary insights into the needs and requirements specific to field hockey. The athletes in the training attended were part of an amateur hockey team in Noord-Brabant. The players were aged between 19 and 24 years old. This particular team has a training frequency of two training sessions, each lasting about 90 minutes per session. Additionally, the team competes in a minor competition, with matches every week or every other week. From these observations, a few initial requirements, both technically and functionally, surfaced. Firstly, players seemed to have a great preference for game-based training exercises. The level of enthusiasm as these exercises were announced was notably higher than when ‘traditional’ more repetitive exercises were announced. In addition, players seemed to be more engaged in the game-based exercises.

Secondly, the contents of the training session are tailored and specific to skills that were underrepresented in a previous match or competition. In addition, for some exercises, the team was split into smaller groups, training specific training goals. This created a personalised experience for the players, however, at times this put extra strain on the trainer trying to supervise multiple activities

Thirdly, technical skills such as passing are largely already trained at a distance, with players standing on opposite sides of the field, practising passing and accepting skills. Conversely, tactical skills such as passing a ball under pressure from an opponent, could not be replicated at a distance.

Lastly, exercises are often set out with cones. At the end of the session, the cones are often not in the same spot anymore, due to being hit by balls or sticks throughout the exercise. A system with electronics in it is more vulnerable to the impact of balls.

5.4.Conclusion and Discussion

From the observations and interviews and background research, the preliminary requirement list can be composed. Firstly, the application of the system should be diverse and should cater to different types of athletes and preferred training styles. These variations should be in the level of intensity but also in training goals. Secondly, the exercises should include tactical skills and small-sided game elements. Research shows many perceived benefits of small-sided games. In addition, this method of training was proposed by the KNHB and seemed to be the preference of the players interviewed. Thirdly, in times of corona, where social interaction is lacking, the 'fun and recreational' element of sports is important. Finding a good balance of engaging but useful training exercises is important. This can be achieved by mixing and matching the exercises but could also be reflected in the design of the exercises themselves. Lastly, the nodes should ideally be wireless and should have some form of protection from the impact of balls.

5.5.Initial concept

From the initial requirements identified earlier, a preliminary concept can be derived. The outcome of this Graduation Project is a set of exercises that each represent a different training goal. The design is modular so that trainers and coaches have the freedom to mix and match exercises to the specific needs of their athletes and to their preferred training styles. In addition, the intensity of the exercises should be manageable by the trainer, either by repeating cycles of the exercises or by decreasing the number of players or pitch size. In addition, as training technical skills does not seem to be as impacted by social-distancing rules as tactical skills, the focus of the exercises developed are tactical skills. These tactical skills are trained through small-sided game exercises. These SSGs not only proved to have more positive health outcomes but were also preferred by the KNHB and the athletes themselves. Non-specific tactical skills for invasion sports, as defined by Memmert and Harvey [46] should be considered, so that future research could easily adapt and extend the outcomes of this thesis to other invasion sports. Lastly, on a more technical ground, the SixFeet system architecture should have a protective base to withstand the impact of balls and sticks. In addition, the nodes, preferably, should be wireless, to avoid athletes tripping over the wire, or balls or sticks getting trapped behind the wire.

Overall, the outcome should be a modular design, with each small-side game exercise addressing a different training outcome, that can be varied in intensity.

6. Specification

This chapter provides an overview of the specification phase. This includes a specification of the system architecture and the to-be-developed exercises. The outcomes of this phase build upon the initial requirements and findings of the Ideation Phase and are formed by a back-and-forth brainstorming and consultation with hockey trainers and experts. The first part of this section translates some of the previously identified requirements to the system architecture. The second and last part covers the co-creation of the exercises.

6.1.Requirements for the System Architecture

From the initial prototype and the outcomes of the Ideation Phase, a set of requirements specific to the system architecture can be made. Firstly, the wires form a tripping hazard. This is even more so the case for field hockey, where the sticks could potentially get trapped by the wires as well. In addition, the wires limit the expandability of the system as nodes cannot easily be added or removed from the configuration. Moreover, having more flexible configuration options, the nodes could be placed further apart to increase the intensity of the exercises. All in all, the system should be wireless.

Secondly, the foot switches do not offer a natural user experience. Players are obstructed in their play as they have to carefully press a button each time before they can continue in their game. For that reason, a sensor of some sort similar to the solutions of SmartGoals [15] and FitLight [16] should be implemented to provide the most unobtrusive user experience possible.

Thirdly, the first prototype was not designed for the impact of balls. As hockey balls can create strong impacts, it is important to protect the internals of the prototype for those impacts. Systems such as SmartGoals [15], which are specifically designed for hockey, feature weighted injection-moulded bases, that prevent balls from bouncing upwards to the more fragile top part of the station. A similar approach can be taken for SixFeet, where a weighted base is attached below the casing of the prototype, which can absorb some of the impacts of lost balls hitting the stations. Additionally, the shape of this weighted base can also be used as a feature for the user interaction when activating a station.

Fourthly, ideally the system should be reasonably weatherproof. Covid-19 and with that social distancing rules and restrictions for sports are mostly prevalent in the fall and winter seasons, therefore the stations would be subject to these weather conditions most. In addition, hockey is increasingly played on water-based turf fields, causing water sprays from passing balls. The system should not only be playable on regular fields and in dry weather conditions. and therefore should be resistant to these conditions.

However, given the scope of this Graduation Project and the secondary focus on the system architecture, this requirement is not taken into account. In addition, as the evaluation phase will take place at the end of Spring, it can be reasonably assumed that the weather conditions do not form a major issue for the user testing. It would require a lot of extra time to create a weatherproof system, taking away from developing the exercises.

Lastly, considering the initial prototype, the requirement of the visibility of the LED lights remains. The LEDs should be clearly visible to avoid confusion and obstructed gameplay. Finding and searching for the lights is not the main objective of the exercises. Players should not be hindered in their immersion in the exercises. Therefore, the LEDs should be easily visible to the players.

6.1.1. Overview of the System Architecture Requirements

The above-mentioned requirements can be summarized in the following list of requirements for the prototype of the system architecture for this Graduation Project:

- Wireless: to avoid tripping and increase set-up flexibility. Having more flexibility in the set-up configuration can also help vary the intensity by increasing the distance between nodes;
- Motion-activated: to help create an immersive and unobstructed user experience.
- Sturdy weighted base: a weighted base can absorb impacts from balls to protect the internals of the prototype;
- Clear visibility of the LED lights: again to help create a more immersive and unobstructed user experience.

6.2. Co-Design of the Exercises

The exercises are created in a co-creative design method, together with two hockey trainers. The first part of this subsection will introduce the co-creators of the exercises. The following parts will provide an overview of the brainstorming and design sessions. Lastly, the final part will provide an overview of the findings and outcomes of these sessions.

6.2.1. Co-Designers

There are two coaches involved in the co-design of the exercises. Firstly, Bart van Mossel, a trainer who has experience training several teams, from junior to senior teams. In addition, he plays in a senior team himself as a forward. This all provides him with the perspective of a player and a trainer.

Secondly, Robert van der Horst. Robert is a retired international hockey defender, who has won silver in the 2012 Olympics and was named the best hockey player in the world in 2015 by the international hockey association FIH [63,64]. He is currently the head coach of hockey club Oranje-Rood in Eindhoven. As a retired elite player and current head coach of one of the most successful hockey clubs in the Netherlands, he can offer a multi-perspective view to design exercises meaningful to both the player and the training objective for elite and amateur players.

Together, these trainers provide a broad perspective on designing training exercises for hockey as they can use their own experiences as a trainer but also as a player, in different playing stages and categories.

6.2.2. Initial meeting

The initial meeting with both trainers went via a Teams video meeting. This session was mainly used as an introductory session, where the trainers were introduced to the concept of SixFeet. When first introducing the concept to the trainers, they immediately responded enthusiastically. Robert shared that semi- and professional teams were at some points still allowed to continue training during periods of lockdown and social distancing. During these periods, social distancing also applied to their training sessions, making it especially difficult to create meaningful training exercises that adhered to this 1.5-metres distance rule. Bart added to this that law enforcement often came to check if the training was adhering to all covid measures, making them feel even more restricted in their training possibilities. He said that many of the in-theory 1.5-meter exercises caused difficulties in practice in terms of keeping distance, as a result of user error, confusion and different speeds at which players perform the exercises. In addition, they commented that the system itself, with or without the algorithm, presents an interesting way of training that allows for interesting training opportunities that were previously not possible, as the system allows for effective combinations of technical and tactical training goals, in a single exercise.

6.2.3.Second meeting and brainstorming session

The second meeting took place in Asten, at the company of Robert van Der Horst. An early version of the prototype, without any of the code, was present to provide a visual for designing exercises and user interactions with the stations. The desired outcome of this session is six exercises; three exercises without the SixFeet system representative of exercises used during social-distancing training sessions, and three exercises fully using the SixFeet system. During the evaluation phase, these two different types of exercises can be compared.

During this meeting, the user testing groups were also decided. The system is going to be evaluated with two senior men's teams in Eindhoven. As established in Chapter 2, it is important to take into account the type of player when designing a meaningful training. The training should be in line with the development of sports skills learning stage, to be as effective as possible [52]. Furthermore, the first step in designing a hockey training is to take note of the starting position of the team and individual athletes according to the KNVB. Therefore, with this in mind, the training exercises should be designed with a specific type of player in mind. However, the exercises should be variable so that they can easily be adapted or simplified if other types of players wish to use them for their training regimens. Following this, the focus of the exercises lie on the specific training stage of the senior teams.

Considering the intended group of players, a few training outcomes were established that should be included in the final exercises. The exercises should combine technical and tactical training outcomes into one exercise, creating a more representative and meaningful way to train these skills. The training outcomes that were relevant for the intended player group were; looking up from the ball, passing techniques, tactical dummy pass, turn techniques and playing together. Especially the tactical skill of playing together was focused on, as this is an element that was barely possible in existing exercises.

Initially in this session, a few concept exercises were developed for three players. However, after some considerations after this session, this was changed to four people, of which two are inside of the playing field and two outside of the playing field. There were a few reasons for this. Firstly, adjusting the existing algorithm to include three players was more work than initially anticipated. The time that would have to be invested in this would not outweigh the benefits. Additionally, adding a third person would alter the algorithm fundamentally which would create more uncertainty about the functionality of the algorithm rather than provide a focus on the exercises themselves. Moreover, by having exercises for four players, there is more opportunity for training tactics, such as playing together. Finally, having two players participating outside of the playing field provides a new and previously unexplored element for creating exercises.

6.2.4.Final meeting before Realisation Phase

The third and last session before the realisation phase again took place online via a Teams video conference. In this session, the concepts for the training exercises were finalized, which are further tested and improved during the realisation phase. The initial concept exercises that were drafted in the previous meeting were adjusted to include two players inside and two players outside the circle, instead of the previous three players in the circle configuration. During this meeting, a date was set on which the exercises could be tested before the evaluation phase, to see if the user interaction with the prototype is as intended.

6.2.5.Overview of Outcomes of Co-Design Sessions

The exercises that were designed during the Co-Design sessions are basic in the sense that they can easily be adjusted to address different training outcomes, such as different passing techniques. This gives the trainers freedom in curating a full training that is adjusted for the specific needs of their team. For this specific evaluation phase, with the senior teams, the exercises were adjusted to best fit the needs of these teams. The techniques addressed in the exercises reflect techniques that, based on competition results and observations, are relevant to these specific teams.

7. Realisation

Similar to the previous sections, the realisation phase has a two-fold nature; the realisation of a prototype version of the system architecture and the realisation of the training exercises for that system architecture. The first part of this section will cover the realisation of the prototype based on the requirements as defined in the specification phase. The second part will build on the outcomes of the specification phase to finalize the exercises that will be used in the evaluation phase. The last part will provide an overview of all materials used and an overview of the user interactions and in what ways the system architecture further facilitates the exercises. The outcomes of this phase are used in the evaluation phase.

7.1.System Architecture Prototype

This section will cover the hardware and the software elements of the prototype. In total, the prototype comprises 8 stations. All stations are identical. In addition, there is one 'master' station that is not part of the configuration. This master is further explained in the following section. The first part will provide an overview of the hardware of the prototype. The second part will provide insights into the electrical components. The third part will provide an overview of the complete prototype. The fourth part will cover the software and coding elements of the prototype and the following part will provide an overview of the user interaction. Lastly, the outcomes of a preliminary user testing session are shared.

7.1.1.Hardware

The hardware comprises 2 main parts, the casing of the prototype itself, and the weighted base that absorbs any impacts of balls hitting the stations. This subsection provides an overview of each part and shows how they are used together.

7.1.1.1.Weighted Base

As the scope and resources of this Graduation Project limit possibilities for a weighted base, a creative solution had to be found. This solution comes in the form of a parasol base weight (see Figure 9). Normally, these are used to weigh down tents and parasols, so that they don't get swept up by the wind. The bases are empty plastic containers, that can be filled with either water or sand. As there are electronics sitting on top of this base, the bases were filled with sand rather than water to avoid any water damage to the electrical components. Filled with sand, each base weighs around 3.5 to 4 kilograms. The bases have a diameter of 25 centimetres and are 6 centimetres tall. Due to the rounded edge design, balls bounce off well from the sides without bouncing upwards in the direction of the more fragile electrical components.

Figure 9: Parasol Base [65]

7.1.1.2.Casing of the Prototype

As there are not many options for a sturdy weighted base, therefore, the casing of the prototype was made to fit the weighted base. The casing that houses all electrical components is a simple laser-cut box of 4-millimetre plywood as shown in Figure 10. The finger joints are glued together using regular wood glue. The box measures 15x15x8 centimetres, so that it fits comfortably on the weighted base, while also having enough room for all electrical components. The design for the box was created using makercase.com [66]. There are two small slots on the lid of the box. The first slot is used for the wires of the LED ring that lies on top of the lid. The second opening was originally meant for the wires of the distance sensor, which was supposed to also go on top of the lid. This, however, changed as the position of the distance sensor is no longer on top of the box. Nevertheless, the slot still has a purpose, as the lid fits rather tightly on the box, and the small opening serves as a grip to help open the box to reach the internal components.

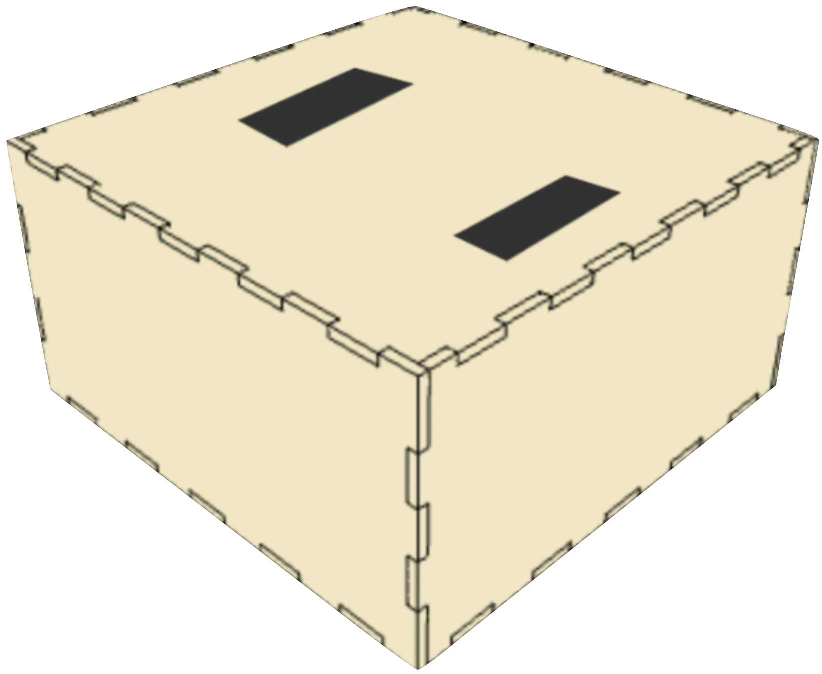

Figure 10: Render of the prototype casing [66]

7.1.1.3.Complete Hardware

The weighted base and the casing are attached to each other by a laser-cut circle of 4-millimetre plywood and a few 3d-printed elements. The casing is attached to the 20-centimetre diameter laser cut circle with four small screws. The weighed bases have a number of holes on both sides, which are used to securely attach the casing on so that it does not move or wiggle around upon impact of a ball. To do that, a set of four 3d-printed legs are created, that perfectly fit inside the holes of the weighted base. The legs are attached to the laser-cut circle by small screws. To make sure that the casing securely stays in place, another 3d printed part is used between the opening of the weighted base. This is attached to the casing with a long screw. Figure 11a provides a schematic of the side view of how the casing and weighed base are attached and Figure 11b shows a schematic of the top view of the hardware part of the prototype.

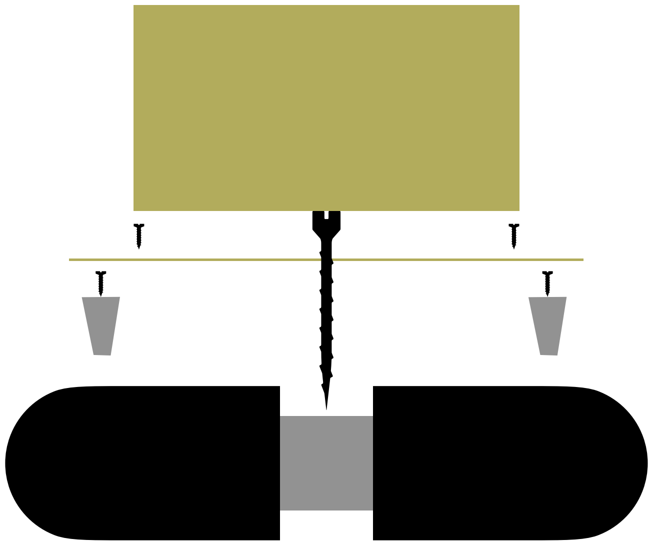

Figure 11a: schematic side view of hardware

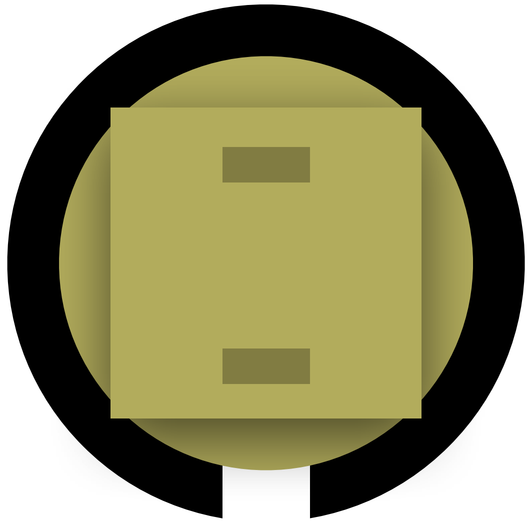

Figure 11b: schematic top view of hardware

7.1.2.Electrical Components

There are several electrical components involved in the prototype. Each subsection will highlight one of the electrical components. The last subsection will provide an overview of the wiring is provided.

7.1.2.1.NodeMCU [67]

The brain of each station is a NodeMCU 1.0 ESP8266 board [67]. These boards are similar to Arduino [68] boards, which are microcontrollers that are often used in prototyping with electronics. As opposed to regular Arduino Uno boards, the NodeMCU boards used for this project feature an additional ESP8266 chip that allows for wireless communication. The NodeMCU board requires a 3.3-volt power supply. The NodeMCU boards can make use of the same Integrated Development Environment (IDE) as Arduino and has Digital pins similar to Arduino, therefore the NodeMCU board can be used as a standalone microcontroller and does not require an Arduino to be connected to it. Alternatively, an ESP8266 module can be added to an Arduino board to create a similar effect.

Similar to an Arduino Uno board, the NodeMCU can be connected via a serial USB connection, to upload new source code. This could alternatively also be done Over-The-Air (OTA), which can be helpful in projects where many boards are used. Additionally, this allows for quick iterations in the code, without having to physically connect each board to a computer.

7.1.2.2.HC-SR04 [69]

The HC-SR04 is an ultrasonic sensor that is capable of measuring objects at a range of 2 centimetres up to 4 meters, with an accuracy of up to 3 millimetres. The sensor has two transducers, one that sends out an inaudible sound signal and one transducer that receives this sound signal. The HC-SR04 is used to register a player arriving at a station. The user can 'activate' a station by closely moving in front of the station. As opposed to the NodeMCU board, the HC-SR04 requires 5 volts of incoming power to function properly.

7.1.2.3.RGB LED Ring WS2812B 12-Bit Neopixel [70]

The LED ring used for this prototype is slightly different to the one used in the previous prototype. This LED ring is 12-bit as opposed to 8-bit, to improve the visibility of the LED. All LEDs are RGB and are individually programmable. The Ring has 4 pins, of which 3 are used for this prototype. The Vin pin is used to supply the ring with 5 volts of power, the Ground pin is used to ground the ring and the D1 pin is used to communicate data with the ring so that it knows when in and in what colour to light up.

7.1.2.4.Breadboard Power Supply [71]

To accommodate for the varying required power inputs of the other electrical components, a breadboard power supply is used, that can supply two different voltages at the same time. A 9-volt battery is attached to the power supply via a DC plug. The power supply splits this incoming power into two channels, of 5 volts and 3.3 volts respectively. The power supply also has an on/off switch.

7.1.2.5.Wiring

Figure 12 shows a wiring diagram of the prototype. The NodeMCU is connected to the power supply's 3.3 volts channel. The distance sensor and LED ring are both powered by the 5-volt channel of the power supply. There are 3 digital pins in use on the NodeMCU board, two pins are used for the distance sensor and one pin is used for data for the LED Ring.

Most connections are made using protowires, rather than solder connections. From previous experience with the old prototype, the solder connections tend to break upon impact and are not quickly solved on-site. For that reason, protowires were used. In case a wire gets loose, it can easily be put back in, without the need for a soldering iron.

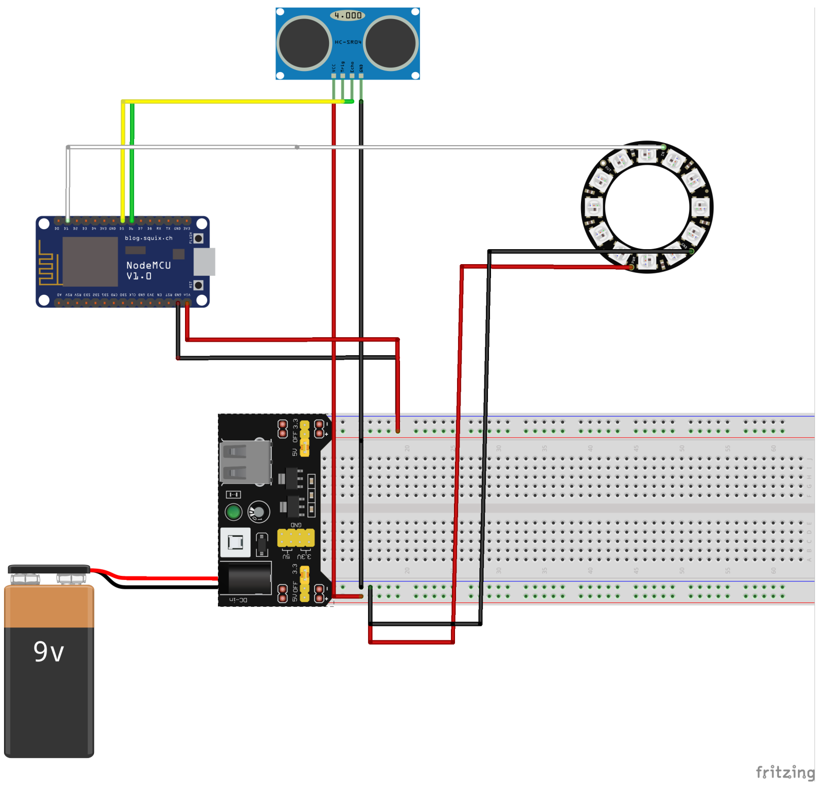

Figure 12: Wiring schematic prototype

7.1.3. Complete Prototype Overview

Putting all elements together, the complete prototype is formed. The LED ring is glued on top of the lid, the distance sensor is attached to the inside side wall of the casing and all electrical components are attached to the inside of the casing. Figures 13 and 14 show a complete overview of the finished prototype. Figure 26 shows the prototype exterior and Figure 27 shows the inside of the prototype, with all electrical components, apart from the LED ring which is glued on top of the lid.

Figure 13: Exterior of the prototype

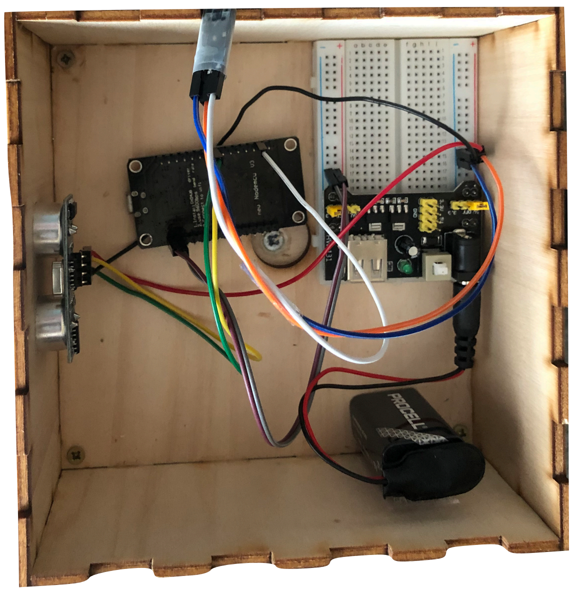

Figure 14: Internal structure of the prototype

7.1.4.Code and software

There are multiple scripts used to control all stations. Firstly, there is a communication protocol that takes care of the communication between the stations and the algorithm. There is a separate script for the stations and the master node. Secondly, there is a separate script that houses the algorithm. The following subsection addresses each of these scripts.

7.1.4.1.Communication Protocol

Having a reliable and fast communication protocol is essential for the prototype. To achieve this, the ESP-NOW protocol is used. "ESP-NOW is a connectionless communication protocol developed by Espressif that features short packet transmission. [72]" ESP-NOW does not use Wi-Fi, but rather a protocol that requires a pairing first. After this pairing, the connection is stable, persistent and peer-to-peer. In case of a power loss on one of the boards, the connection is automatically continued once the power is regained. Up to 250-bytes can be sent per message. Messages can contain multiple variable types such as characters, floats, integers and booleans. The number of peers however is limited, to a maximum of 20. [73]

Each board has its own MAC address, that can be used to identify each board and to send messages between boards. A simple code can be uploaded to output this unique MAC address to the serial monitor. The MAC address can be customized, however, upon a restart the MAC address is restored to default. Therefore, a list of all default MAC address is made to distinguish the stations.

A board can either be a sender or a receiver or both. In the case of this prototype, all boards are both senders and receivers. The code of all boards, therefore, includes the following elements [72]:

- Command to initialise ESP-NOW
- Command to register a callback function when data is sent. This checks if a message was delivered or not.
- Command to register a callback function when data is received. This checks if a message was received or not.
- Command to add peers. This command uses the MAC addresses of the peers.
- Command to send a message to the peer(s).

Since each station both receive (colour) and sends (activated or not) messages, there is strictly speaking no real slave-master hierarchy. Rather, the role of all stations is set as multi, meaning they can both receive and send messages. There is, however, one ESP-8266 board that is connected to a laptop outside the playing field. This board is responsible for the smart-allocation algorithm. For simplicity, the ESP-8266 board connected to the laptop is referred to as the master and the 8 stations are slaves.

The communication range between two boards is about 220 meters in an open field [72]. This distance is not necessary for this application, however, since the boards are inside a casing, having a large range helps with the stability and reliability of the system.

7.1.4.2.Algorithm

The algorithm used for this prototype is largely the same as for the first prototype, as explained in Section 3. However, a few elements are different. Firstly, the players do not choose their own starting position, rather this is predetermined by the trainer. This allows more control for the trainer and prevents accidental activations when setting up the system as stations are now more easily activated due to the distance sensor.

Secondly, the original code included breaks. These breaks were inherent to the high-intensity interval training format that the original game followed. However, for this prototype, the breaks were removed from this prototype, as they were not needed or relevant for the newly developed exercises.

Thirdly, the sound cues are removed from the code. The sounds were used for the initial high-intensity interval game to give information to the user on when the breaks start and end. As there are no longer breaks, the audio is no longer necessary.

7.1.4.3.Overview of Code

In total, there are 3 different codes. Firstly, all 8 stations have the same code and can only send messages to a so-called 'master' node. This master node is a single NodeMCU board connected via USB to a laptop. There are no other electrical components attached to this board, it merely functions as an interface between the processing code that houses the algorithm, and the 8 nodes. The code that is uploaded to the stations can be found in Appendix A.

Secondly, the master node. This code is similar to the code of the stations, the main difference being the communication with the processing code and the ability to send messages to all the stations. As the master is connected to the laptop via USB, the communication between the master and processing goes via serial communication. The code that is uploaded to the master can be found in Appendix B.

Lastly, the processing code. This code runs on the laptop to which the master is connected. Through serial communication, the processing code sends and receives messages from the master. The processing code is only responsible for housing the algorithm and sending serial messages to the master on which nodes need to light up in what colour. The processing code can be found in Appendix C.

7.1.5.Overview of System Architecture

An overview of the system architecture can be seen in Figure 15. This figure shows a simplified version of how the user interacts with the system and how the code is processed.

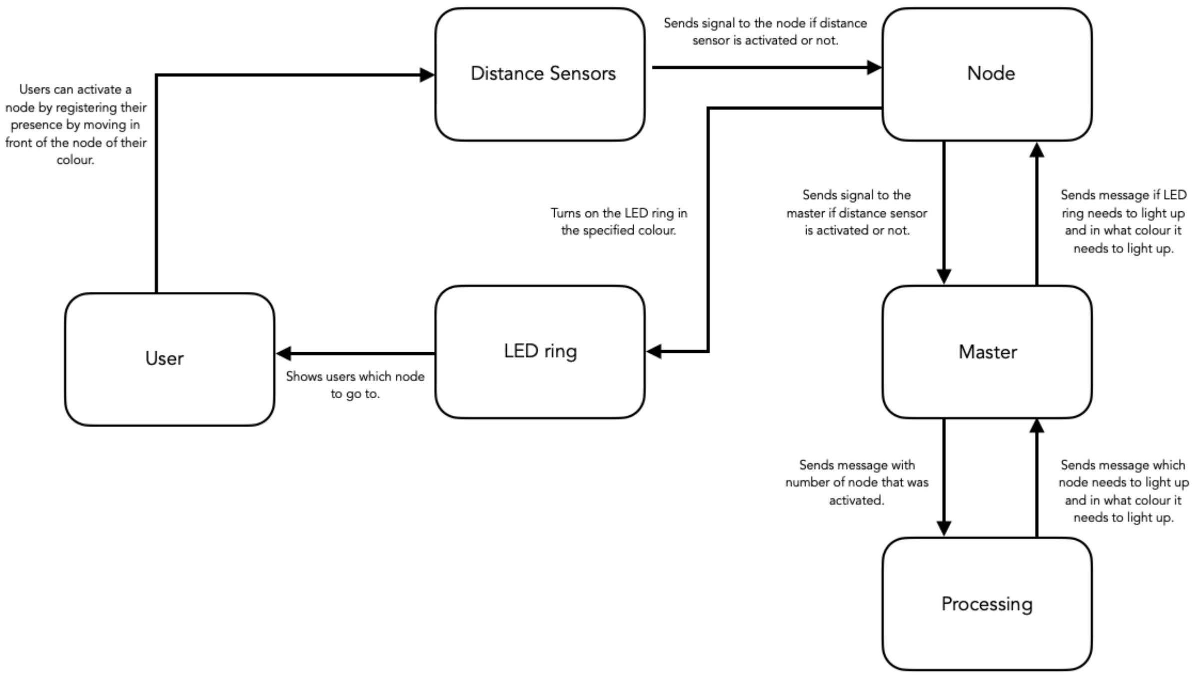

Figure 15: Overview of System Architecture

7.1.6.Preliminary User Testing

During a preliminary test, the user interaction and the exercises were tested to see if they were as intended. This test yielded a few outcomes that helped prepare for the formal user evaluation. Firstly, the nodes have to be more than 1.5-metres apart. As it is part of the exercises to walk around the stations, the players breach the distance rule if the stations are only 1.5-metres apart. Additionally, having them further apart created a more interesting exercise for the players.

Secondly, the position of the distance sensor should be changed for some of the exercises. The distance sensor only registers objects if they 'cover' both transducers. Therefore, when players move around or move their stick and ball around the station, it should be taken into account that at the moment in which they pass the distance sensor the stick should be at the flattest position to be able to cover both transducers. For some exercises, this meant that turning the distance sensors towards or away from the playing field resulted in easier activation.

Lastly, the distance at which the nodes register a player was increased. The distance was increased to make the nodes activate easier. Before, the distance was set at 30 centimetres. This made that the only way to activate a node was to put a stick closely in front of the sensor, which interrupted the user immersion. For this reason, the distance was changed to 70 centimetres. Making the distance even larger would result in some false activations.

7.2.Exercises

A total of six exercises are developed for the evaluation phase. Three exercises that represent 1.5-metres training exercises without using the SixFeet system and three exercises that use the SixFeet system. The first part of this subsection outlines the SixFeet exercises and the second part will outline the 1.5-metres or 'dummy' exercises.

7.2.1.SixFeet exercises

Building on the outcomes of the Specification Phase, three exercises were developed especially for SixFeet. All three exercises are designed for four players. Each exercise can be varied in many ways, for example by changing the user interaction at the stations or by changing the passing method. This way, trainers have a lot of freedom to adapt and alter these exercises to fit their specific situations.

7.2.1.1.SixFeet Exercise 1 (Figure 16)

Materials:
- 4 players
- 2 balls
- 8 stations (configured in an octagon)
- 2 cones

Explanation:
- Player A (red) and B (Blue) both start with a ball at a predefined station. From here on, the exercise starts and players A and B follow their respective colors while dribbling the ball.
- At stations 2,3,6 and 7 player A or B makes a forehand turn around the station. After this, the player looks up and moves to the next station in their respective colour.
- At stations 0,1,4 and 5 player A or B passes their ball to player C or D, who are situated at one of the cones outside of the circle. Player C or D steps to the side, depending on which station player A or B is at and receives the ball and passes the ball back. After receiving their ball back Player A or B looks up again and moves to their next station in their respective colour. Player C or D move back to the cone.

Training goals:
- Looking up from the ball
- Dribbling
- Forehand turn
- Passing and Receiving
- Playing together

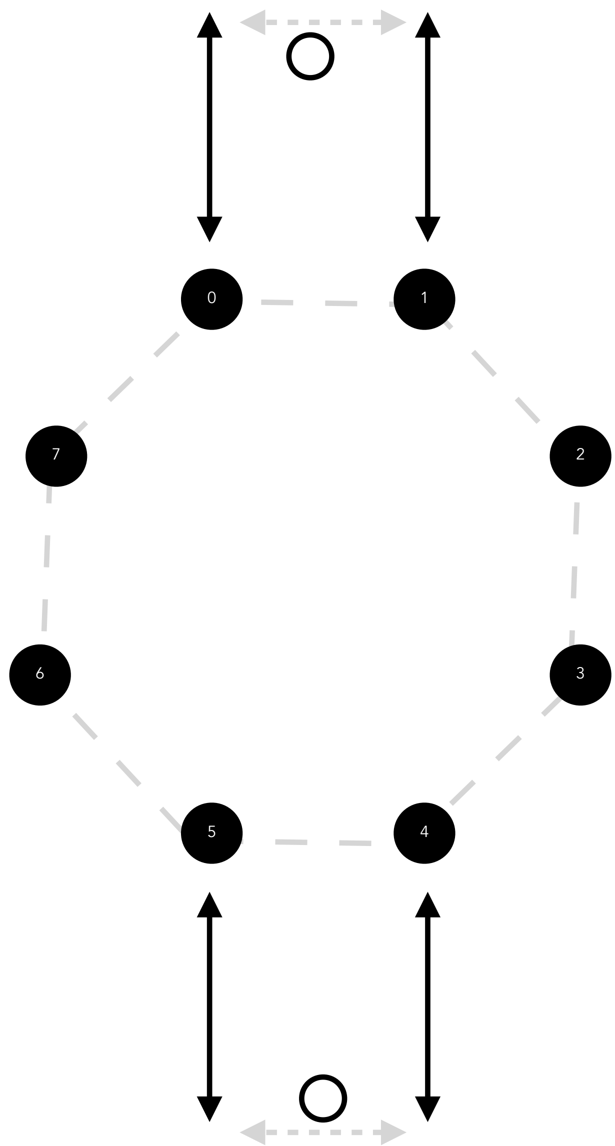

Figure 16: SixFeet Exercise 1

7.2.1.2.SixFeet Exercise 2 (Figure 17)

Materials:
- 4 players
- 2 balls
- 8 stations (configured in an octagon)
- 4 cones

Explanation:
- Player A (red) and B (Blue) both start with a ball at a predefined station. From here on, the exercise starts and players A and B follow their respective colour while dribbling the ball.
- At stations 1,2,3,5 and 7 player A or B perform a dummy in front of the station and turn around the station afterwards. After this, the player looks up and moves to the next station in their respective colour.
- At stations 0 and 4 player A or B passes their ball to player C or D, who are situated at one of the left cones outside of the circle. Player C or D receive the ball and dribble to the next station lighting up in the colour of player A or B. After passing the ball to player C or D, player A or B runs via the right cone to the left cone.

Training goals:
- Looking over the ball
- Ball control
- Dribbling
- Running without ball
- Dummy pass
  - Dummy pass is a technique in hockey. It can be performed to the left and right. It is a technique that confuses the opponent on which side the ball is going to pass, by changing the direction of the ball at the very last moment.
- Passing and Receiving
- Playing together

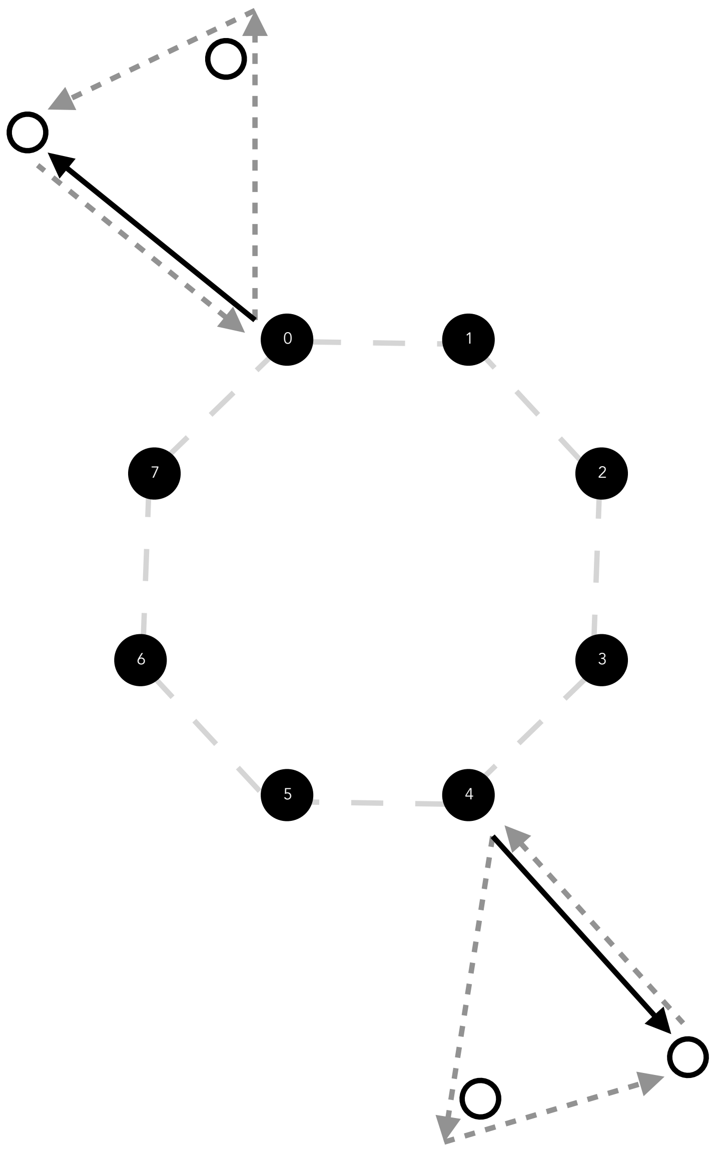

Figure 17: SixFeet exercise 2

7.2.1.3.SixFeet Exercise 3 (Figure 18)

Materials:
- 4 players
- 2 balls
- 8 stations (configured in an octagon)
- 4 cones

Explanation:

- Player A (red) and B (Blue) both start with a ball at a predefined station. From here on, the exercise starts and players A and B follow their respective colour while dribbling the ball.
- At stations 2,3,6 and 7 player A or B perform a backhand turn around the station. After this, the player looks up and moves to the next station in their respective colour.
- At stations 0, 1, 4 and 5 player A or B passes their ball to player C or D, who are situated at one of the left cones outside of the circle. Player C or D run from the center to the cone where player A or B passes the ball to, depending on which station player A or B is situate at. Player C or D receives the ball. After receiving the ball, player C or D backhand passes the ball back to player A or B and runs back to the centre. Player A or B move to the next station lighting up in their respective colours.

Training goals:
- Looking over the ball
- Ball control
- Dribbling
- Running without ball
- Backhand pass and receiving
- Backhand turn
- Anticipating
- Playing together

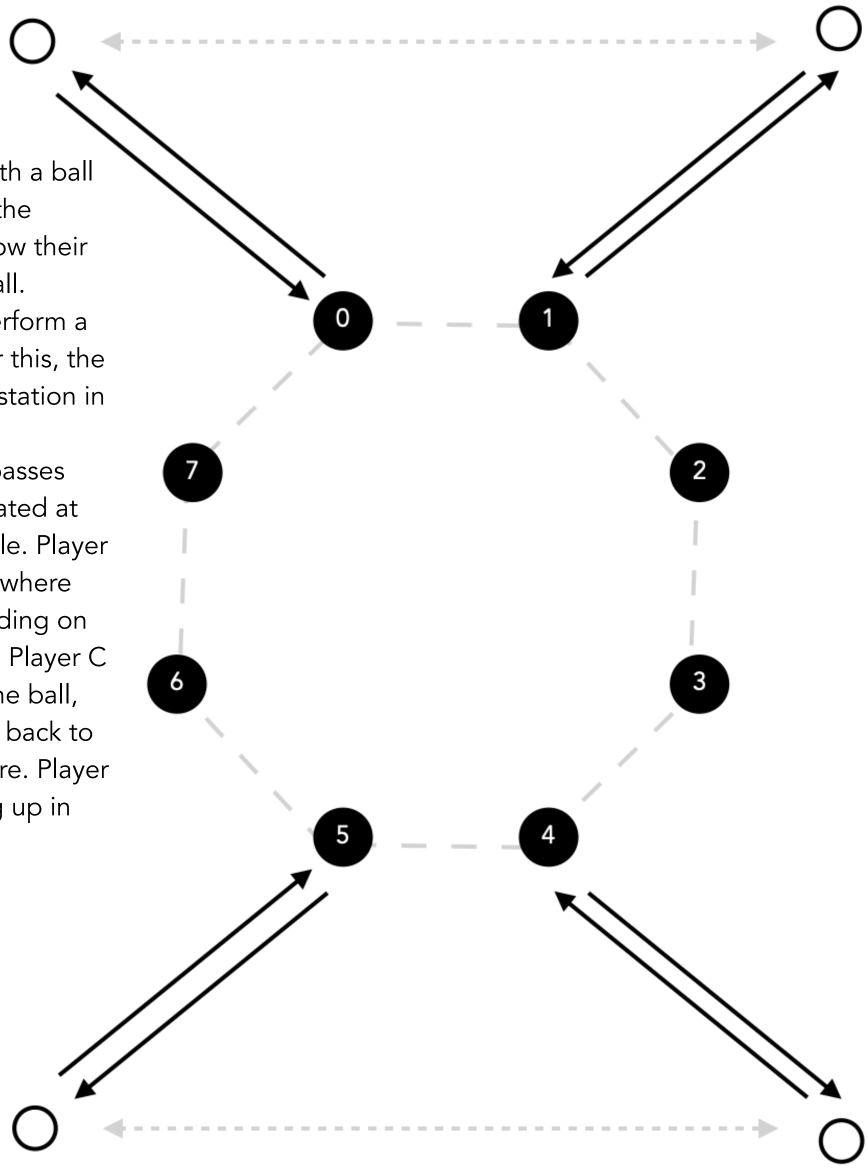

Figure 18: SixFeet Exercise 3

7.2.2.Dummy exercises

In order to evaluate the SixFeet exercises, three representative exercises were created that are used or could be used as 1.5-metres training exercises during times of lockdown. On paper, these exercises are designed so that players keep 1.5-metres distance at all times, however, from practical experience of the trainers, this is sometimes challenging. In addition, the trainers highlighted that it is not possible to address all the training goals in the way they are present in the SixFeet exercises. Despite these limitations, the following three exercises were designed to be as representative as possible. Building on the outcomes of the Specification Phase, three exercises were developed especially for SixFeet. All three exercises are designed for four players.

7.2.2.1.Dummy Exercise 1 (Figure 19)

Materials:

- 4 players, 2 pairs
- 2 balls
- 8 cones (configured in an octagon)

Explanation:

- Player A and B form a pair and player C and D form a pair.
- Player A starts at cone 3, player B starts at cone 6, player C starts at cone 5 and player D starts at cone 0.
- Player A and c pass their ball to players B and D respectively. After player B and/or D receive the ball, both players from a pair move anti-clockwise to the next cone.
- Players B and D pass the ball to A and C respectively. Exercise repeats like above.
- Players have to be careful to not end up at a station where the other pair is playing, if this is the case the pair should wait for the other pair.

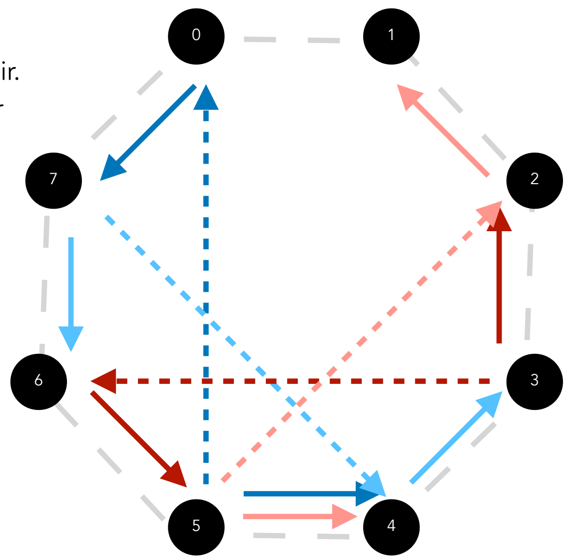

Figure 19: Dummy Exercise 32

Training goals:

- Coordination
- Passing
- Looking up from the ball
- Dribbling

7.2.2.2.Dummy Exercise 2 (Figure 20)

Materials:
- 4 players
- 4 balls
- 8 cones (configured in an octagon)

Explanation:

- Player A starts at cone 0, player B starts at cone 6, player C starts at cone 4 and player D starts at cone 2.
- All players slalom around the cones.
- Players have to be wary of the other players as they cannot overtake other players. They have to adjust their speed accordingly.

Training goals:
- Coordination
- Looking up from the ball
- Dribbling
- Ball control
- Adjusting speed

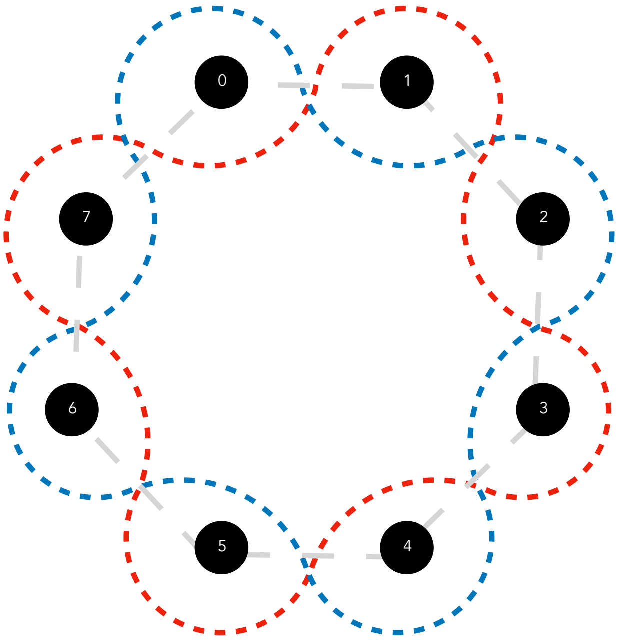

Figure 20: Dummy Exercise 2

7.2.2.3.Dummy Exercise 3 (Figure 21)

Materials:
- 4 players
- 1 ball
- 8 cones (configured in an octagon)

Explanation:

- Player A starts at cone 0, player B starts at cone 2, player C starts at cone 4 and player D starts at cone 6. Player A has the ball.
- Player A dribbles to the next cone, clockwise. Player A passes the ball to player B at the next cone. Player B receives the ball. After passing the ball Player, A moves back to the previous cone. Player B dribbles to the next cone, clockwise. Player B passes the ball to player C at the next cone. After passing, player B moves back to the previous cone.
- The exercise repeats like above.

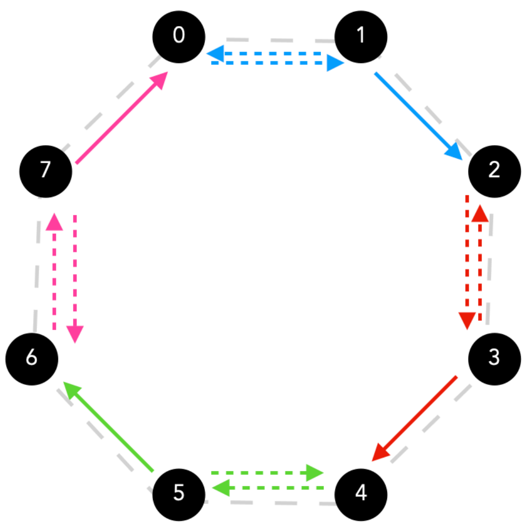

Figure 21: Dummy Exercise 3

Training goals:
- Awareness of the game
- Passing and receiving
- Looking up from the ball
- Dribbling

8. Evaluation

The main objective of the evaluation phase is to assess the application of SixFeet in a sport-specific context. In order to make the existing platform sport-specific, or in this case specific to hockey, alterations to both the system architecture and the user interaction had to be made. This evaluation addresses and asses both these elements. However, since the system architecture and with that the algorithm has previously been established as functional, a focus is put on the functional part of the evaluation, where the developed sport-specific solution for SixFeet is assessed.

The first part of this evaluation covers the evaluation procedure. This section is split into multiple subsections, in which the functional and technical evaluations are each addressed separately. The second part will focus on the results and outcomes of the user testing sessions. Lastly, the outcomes and results of this phase are discussed in more depth in a short discussion.

8.1.Procedure

This subsection outlines the overall procedure of the technical and functional evaluation.Firstly, the general and specific aims of the evaluations are discussed. Following is a subsection about the involved study population. Next, the study design, including the questionnaire, is presented. Following, the experimental setup and the structure of the user testing sessions are outlined. Lastly the analysis plan of the collected data is discussed.

8.1.1.Aim of evaluation

The general aim of the evaluation phase is two-fold, but most specifically focuses on evaluating SixFeet as an enjoyable and meaningful sport-specific training tool that can be used in a 'corona-safe' manner. The secondary objective is to establish, once more, that the algorithm is functioning as intended, however this time in the sport-specific context.

8.1.1.1.Functional evaluation

As SixFeet is meant as a way to allow or enrich training regimens during a lockdown, a comparison to alternative 'corona-safe' exercises without the external help of a system such as SixFeet, is made. The primary objective of the functional evaluation phase is to determine whether training with SixFeet yields a significantly greater sense of enjoyment as opposed to alternative corona-safe training exercises. The secondary objective is to evaluate whether the SixFeet-mediated exercises can provide a more meaningful and useful training experience as opposed to existing alternative exercises.

8.1.1.2.Technical evaluation

The primary objective of the technical evaluation is to determine whether the algorithm is still functioning as intended in the sport-specific context of field hockey. Elements such as the distinct stance of a hockey player, the stick and running with a ball could all be factors that influence the number of close encounters in a session. The technical evaluation aims to quantify those close encounters to see how well the algorithm still functions in the new context. Additionally, the secondary objective of the technical evaluation is to see how well the new prototype performs. The functioning of the prototype might influence the number of close encounters and the perceived enjoyment of the users.

8.1.2.Study population

As this evaluation takes place in late spring, the hockey season is ending or for some has already ended. Therefore, it is challenging to find teams who are still training. Nonetheless, two user groups were found for the evaluation phase.

For the functional evaluation, two different user groups were included. The first group comprises male players from two senior field hockey teams from Oranje-Rood in Eindhoven. The average age of these users ranges between 35 and 45 years old. These users are not professional or semi-professional players (anymore), however, they do play in a high-level amateur league. The second group comprises girls of an A-category field hockey team from HC Tilburg in Tilburg. The average age of these users ranges from 16 to 17 years old. These girls are not professional or semi-professional players either. They are part of the second team in their age category.

Unlike the previous user test, the users did not have to be from the same household as at the time of testing there were no corona measures in place that prevented non-household members from coming into close contact with each other in case the algorithm does not function as designed.

Due to an unforeseen circumstance further elaborated on in the results subsection, the technical evaluation only includes one of the user groups. This is the second user group, the girls of the HC Tilburg team. As the technical and functional evaluations are conducted simultaneously, this did not affect the functional evaluation.

In addition to the participating hockey athletes, the trainers and coaches are included in the evaluation process as well. The trainers and coaches are respective to the participating users and are therefore very aware of the specific needs of their players and team as a whole, providing an interesting perspective on the exercises that are evaluated.

8.1.3.Study Design

For both the functional and technical evaluation, a within-study design is employed. Each participant is subjected to both types of exercises, the dummy exercise and the SixFeet exercises. As previously mentioned, finding participants late in the season is challenging. Having a within-study design helps collect the most data in this scenario. In addition, the within-subject design prevents any individual differences between the participants to influence the results. Conversely, the experience of the first set of exercises might influence the experience of the next set of exercises. This influence might result from fatigue or an element of practice effect as both types of exercises make use of the same playing configuration. To minimize any sequence and order effects, the order in which the participants are presented with each condition is counterbalanced, meaning that some groups start with the SixFeet exercises and others end with the SixFeet exercises.

To gather data, a questionnaire is used. All questions in the questionnaire are answered on a 5-point Likert scale. The full questionnaire as presented to the participants can be found in Appendix D. As all participants are natively Dutch, the questionnaire was also presented in Dutch to avoid any language errors. A translated version of the questionnaire can be found in Appendix E.

8.1.3.1.Questionnaire

The questionnaire comprises four general parts: the Groningen Enjoyment Questionnaire (1), questions about the characteristics of the exercises (2), questions about the ability of the exercises to contribute to achieving certain training goals (3) and questions about the perceived feeling of immersion during the exercises (4). In addition, the questionnaire leaves space for participants to write down any additional thoughts or remarks.

The Groningen Enjoyment Questionnaire (GEQ), is a set of questions developed by Stevens et al. [74]. The questionnaire aims to measure enjoyment in leisure-time physical activity, by means of 10 short questions. Each question is answered on a Likert-scale. The answers to all questions result in a an overall score that quantifies the level of enjoyment.

Enjoyment is evaluated as this is commonly an element of the alternative exercises that is underrepresented. Developing exercises that are enjoyable to its end-users is relevant, as this is often the very thing that is lacking. As this questionnaire is rather short, in comparison to other similar questionnaires, it poses as an ideal method to evaluate enjoyment as time is limited throughout the user testing sessions.

The following part of the questionnaire addresses some characteristics that could be applicable to either set of exercises. Some of these characteristics have a positive connotation, whereas some have a more negative connotation. Some characteristics can be seen as each others opposites; such as fun and boring. The order in which the user is questioned about each characteristic is random and mixed up to avoid straight-lining bias. The words included are: fun, boring, static, dynamic, varied, interactive, clear and monotone.

From earlier conversations with the co-designing trainers, the experience with existing 1.5-metres exercises is often described as static, boring or monotone. It is therefore interesting to see how SixFeet is perceived in contrast to these alternative exercises.

As established in the previous chapters, part of a meaningful training is its ability to address certain training goals. As the exercises were designed for a specific team, they represent training goals relevant for that team. The third part of the questionnaire questions users about how they perceived the exercises to be helpful in achieving their training goals and whether the exercises could help them prepare for a match.

The last section of the questionnaire aims to find out whether the exercises created a sense of immersion in the user. Having to constantly think about keeping distance or being frustrated as keeping distance is difficult can disrupt this sense of immersion, and consequently have an effect on the level of enjoyment of the players.

8.1.4.Experimental setup

The following section describes the experimental setup. Firstly, an overview of all materials used, for both the functional and technical evaluation is provided. Following, the physical setup of the SixFeet system and tools for the evaluation is presented. Lastly, the structure of each user testing session is shown.

8.1.4.1.Materials

The overall list of materials used for the user testing:

- 8 SixFeet stations
- Laptop to run the algorithm on
- Spare 9-volt batteries for SixFeet stations
- iPad for note-taking
- Measuring tape to measure the distance between stations and cones
- Cones
- Hockey balls
- Informed consent forms (Appendix F)
- Information Brochures (Appendix G)
- Pens

Materials specific to the functional evaluation:

- Printed questionnaires (Appendix D)
- 4 clipboards

Materials specific to the technical evaluation:

- Drone (DJI Mavic 2 Zoom) including spare batteries and a micro SD-card

8.1.4.2.Setup

As the technical and functional evaluations happen simultaneously, the overall experimental setup is valid for both these evaluations. Figure 22 shows a side view of this setup. The system is set out as defined in each of the exercises in the realisation chapter. All exercises require the nodes to be arranged in an octagon. Some of the exercises require additional cones to be placed in the setup. The distance between each station ranges between 4.5 to 5 meters. In addition, for the technical evaluation part, a drone hovers directly above the playing field. The camera is oriented at 90 degrees so there is no perspective disorientation in the recorded footage. The drone records at a resolution of 4K at 29.97 frames per second.

The user testing takes place at the hockey club Oranje-Rood in Eindhoven and at HC Tilburg in Tilburg. At both clubs, a quarter of a hockey field is available to set up the testing area. Furthermore, for the setup, it is important that the weather conditions are dry in order for the equipment and prototype not to get damaged

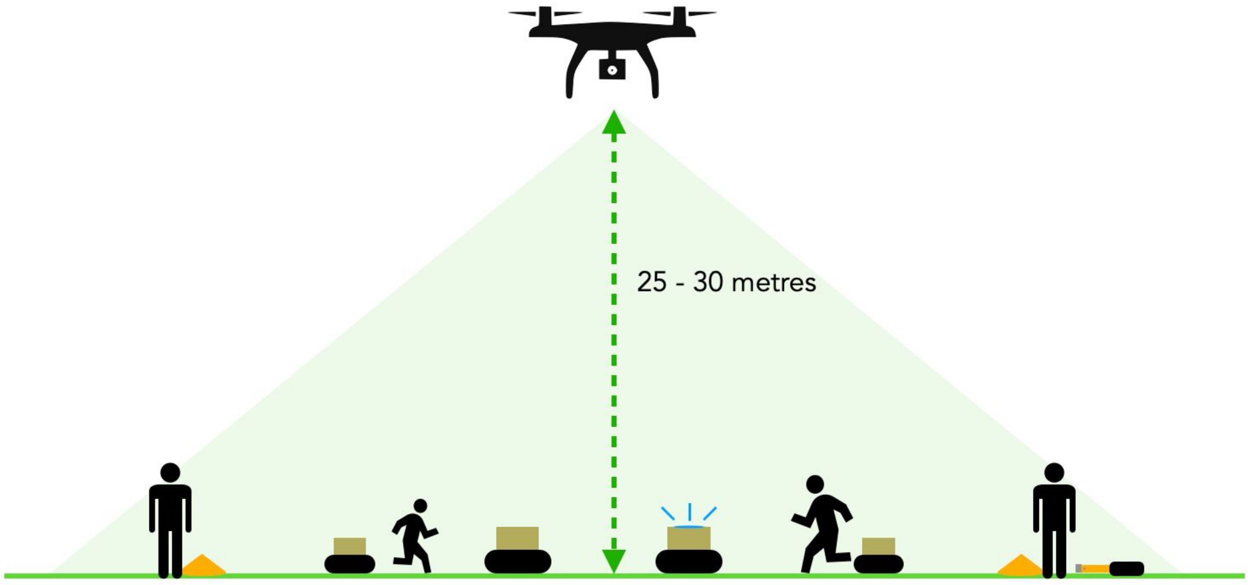

Figure 22: Experimental Setup

8.1.4.3.Structure of user testing sessions

The first and second days of user testing followed a similar experimental setup. An overview of the structure of the user testing can be seen in Figure 23. Before the arrival of the first group of participants, the SixFeet nodes were arranged in the octagon setup that is used for all exercises. At this point, the nodes are not turned on yet to save battery life. Following the arrival of the first participant group, the informed consent forms and accompanying information brochures are handed out on a clipboard. After having completed the informed consent forms, the participants are provided with a general introduction to the user study and the aims of the user study. Simultaneously, all preparations for the following exercise, such as setting up the cones in the correct position and powering on the nodes, are made. Following is a short explanation of the first exercise, as provided by the trainer who is able to explain each exercise in the correct hockey lingo. For the first SixFeet exercise, a demonstration of the interaction with the system is provided, so that users know how they can activate a station. This process repeats itself, until the third exercise. After the third exercise, participants are provided with a questionnaire, to fill in regarding the past three exercises. During the time that the participants are filling out the questionnaire, preparations are made for the next three exercises, such as rearranging the cones and turning the nodes on or off. After filling out the questionnaire, the trainer explains the next exercise, after which the process again repeats. Each exercise took only a few minutes, to minimize any fatigue effects, and to allow for more user tests. After the last three exercises, the participants are asked once more to fill out the same questionnaire, this time regarding the last three exercises. During this time, the system is prepared for the following user group.

In between some sessions, the battery of the drone had to be replaced.

All nodes are turned off in between sessions and during the dummy exercises to save battery life.

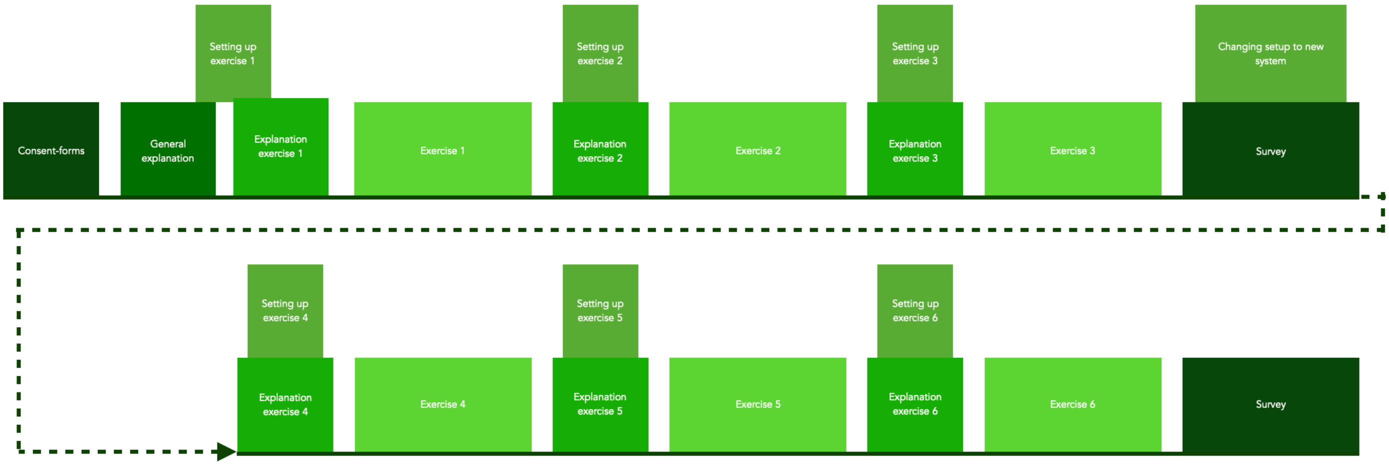

Figure 23: Structure of a user testing session

8.1.4.4.Interaction Protocol

Prior to conducting the experiment, participants are asked to fill out informed consent forms. At this time, participants are informed they are allowed to leave the experiment at any given time, without the need to provide a reason. After filling out the consent forms, users are provided with an overview of the general aims of the study and the procedure during the experiment. The study is introduced to the users as a novel system that allows for 1.5-metres training exercises. The system is being compared to other more traditional 1.5-metres exercises, to see if the system can provide added value to training sessions that are limited by social distancing rules. Both systems were introduced in a neutral way in order to prevent any bias beforehand. The participants are explained that they will try out six exercises, of which three are mediated by SixFeet. After three exercises of each variant, they are asked to fill out a short questionnaire. Before each exercise, their own trainer explains the exercise to the participant, and for the first SixFeet exercise, a brief demonstration of the user interaction with the system is provided. Before filling out the surveys, participants are once more

Although none of the involved participants has a personal connection to this Graduation Project or the researcher, the questionnaires are handed out by someone not affiliated with this Graduation Project to minimize any acquiescence bias. In addition, participants were reminded once more that their responses are treated anonymously, and that their honesty is appreciated as it can help with future developments and improvements of the system.

For the SixFeet questions, users were instructed to try and run from station to station in straight lines as much as possible. Additionally, users were asked to determine what station they had to run to at the station they were currently at, instead of first running to the middle and moving to the next station from there.

8.1.5.Analysis plan

8.1.5.1.Functional evaluation

The elements that are included in the functional evaluation, as defined in section 8.1.3, are analyses as follows. As all questions in the questionnaire are scored on a Likest-scale, each question or set of questions can be accredited a score. These scores can subsequently be compared for the SixFeet and dummy variant. For the Groningen Enjoyment Questionnaire, a total mean score for all questions can be derived, that can then be compared using a paired t-test. The questions related to the perceived levels of immersion are in additionally also checked for any correlations with the GEQ scores. The outcomes of the questionnaire are enriched by observations and remarks from participants and trainers. Neither group agreed to any other video or audio recording besides the drone footage. Due to the position of the drone, these recordings do not recognisably show any persons involved. Therefore, all other observations are recorded using manual note-taking on an iPad.

8.1.5.2.Technical evaluation

After collecting the drone footage, the footage is loaded in software capable of frame-by-frame playback, in this case Adobe Premiere Pro CC, to review all footage. The measuring tape that is visible in the frame is used as a reference to determine what distance is 1.5-metres in the frame. As the drone occasionally moves vertically, the reference distance is updated every time a new, potential breach moment, is analyzed. The occurrences in which players are within or at 1.5 meters from each other are counted for each individual exercise.

In addition, through observations, technical elements such as the visibility of the lights and basic functionality of the system architecture is analysed and reviewed. These observations are enriched by remarks, comments and suggestions of participants.

8.2. Results

This section presents the results and outcomes of the evaluation session. The section is split into two subsections, for the functional and technical evaluation. Each of these subsections also includes a subsection with observations and remarks. The last part of this subsection serves as an intermediary discussion, where the limitations of the user testing sessions are discussed.

8.2.1. Functional Evaluation

Appendix H shows an overview of all data gathered from the questionnaires, where all Likert scale items are scored. Type 1 represents the dummy exercises and type 2 represents the SixFeet exercises.

8.2.1.1. Groningen Enjoyment Questionnaire (GEQ)

As outlined before, the Groningen Enjoyment Questionnaire comprises 10 questions answered on a 5-point Likert scale. Due to a mistake, one question was repeated, and one of the questions was therefore not included. The questionnaire is therefore nine questions, instead of the customary ten questions. The questions were translated to the native language of all participants, Dutch, to minimise any misunderstandings in the questions due to the language. In addition, some of the questions were slightly adapted to fit this specific user test. 'Leisure-time physical activity' was changed to 'exercises' as this represents the user test better. The complete questionnaire, as presented to the participating users, can be found in Appendix D. The English version of the questions can be found in Appendix E.

As each question can be answered on a 5-point Likert scale, scores can be assigned to each answer option. This results in the following scores;

- Strongly disagree = 1
- Disagree = 2
- Neutral = 3
- Agree = 4
- Strongly agree = 5

The distribution of answers to all the individual questions can be found in Table 2 and is visualised in Figure 24.

Table 2: Groningen Enjoyment Questionnaire Scores

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Dummy	10	74	58	27	11
SixFeet	0	3	24	129	24

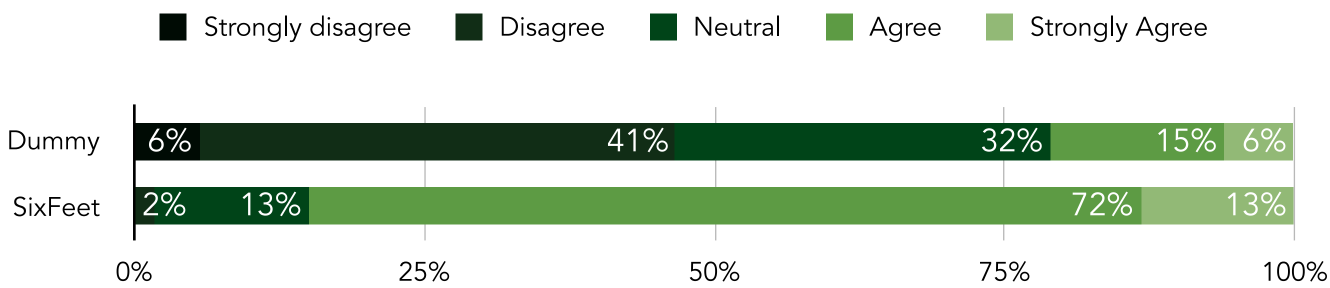

Figure 24: Groningen Enjoyment Questionnaire Scores

The answers to the individual Likert items totaled gives a score that indicates the level of perceived enjoyment. This score has a minimum of 9 and a maximum of 45 points, where 45 indicates the highest level of enjoyment possible. The ranges of the observed scores for the dummy and SixFeet versions are visualised in a box plot figure in Figure 25.

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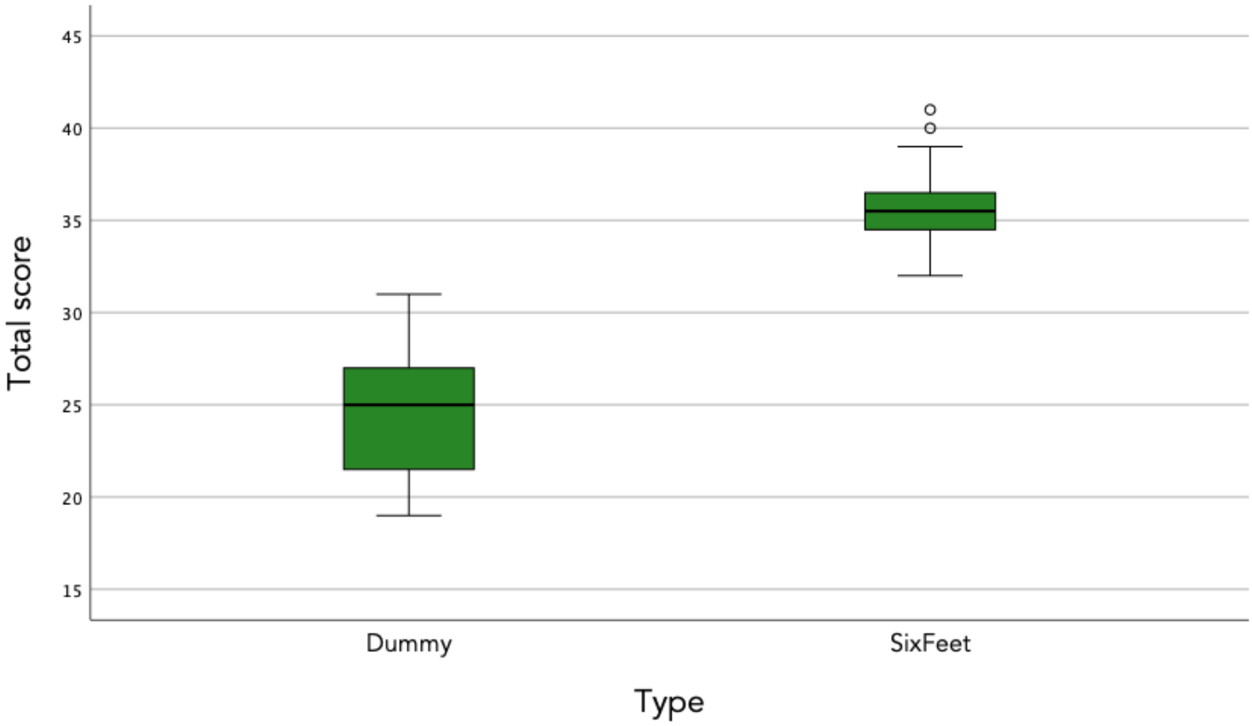

Figure 25: Total enjoyment score distribution

As evident from Figure 25, the range of enjoyment scores lies higher for the SixFeet variant. The mean average score for SixFeet is 35.70, against 24.75 for the dummy version. To test if this difference is significant, a paired t-test is used. Although this method traditionally requires the assumption of normality, a paired t-test can be safely used without this assumption with Likert scale scores, according to Norman [75], and Sullivan and Artino [76].
The paired t-test concluded a statistically significant mean difference of between the perceived enjoyment between the dummy and SixFeet exercises at a significance of .

There is no large difference between the average scores of the different user testing groups for the first and the second day of user testing, as demonstrated in Figure 26.

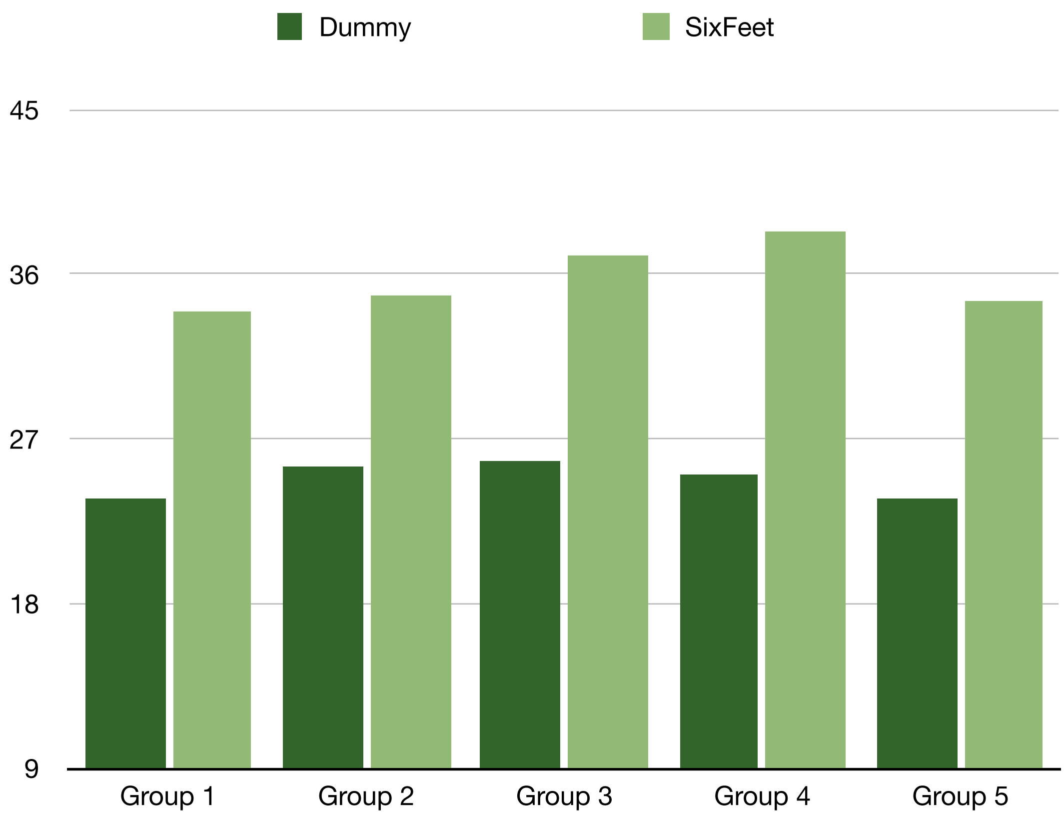

Figure 26: Average enjoyment scores per user testing group

8.2.1.2.Characteristics of the exercises

The second part of the questionnaire contains characteristics that can describe the exercises. The total scores, again based on the Likert scale scores, for each characteristic are visualised in Figure 27. The characteristics are sorted from negatively associated characteristics to positive characteristics for clarity. In the questionnaire, the characteristics are shuffled to avoid non-differentiation. SixFeet scores significantly lower in the negative characteristics and scores considerably higher in the positive characteristics. The clarity is the same for both versions.

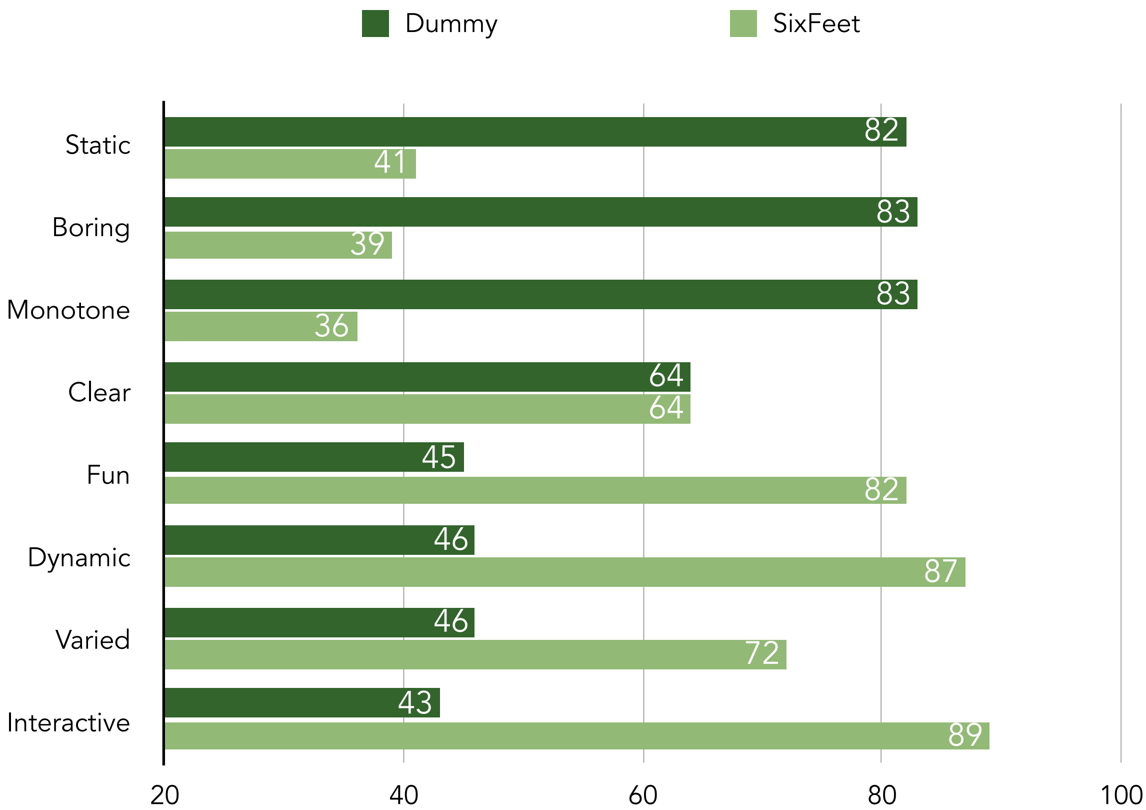

Figure 27: Total scores of characteristic words

8.2.1.3.Training Goals

The three questions in the questionnaire addressing the ability of the exercises to help in achieving training goals and preparing for matches are evaluated in Figure 28. Again, SixFeet scores significantly higher in helping users achieve certain training goals and helping them prepare for matches.

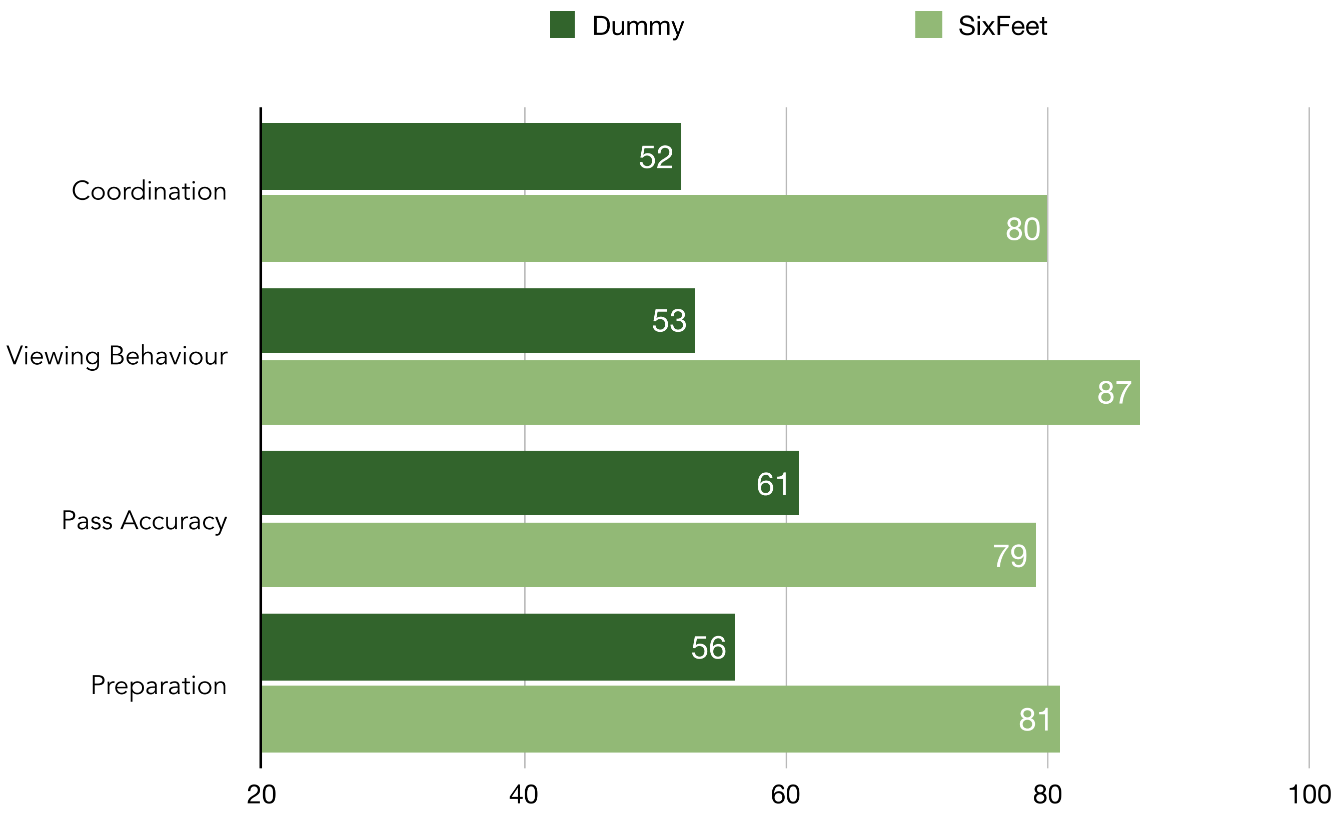

Figure 28: Total scores of training goal questions

8.2.1.4.Immersiveness

The final questions in the questionnaire question the user about the perceived connectedness the experience immersion in the form of connectedness to their team players and the 1.5-metres rule. The total scores of these questions are visualized in Figure 29. SixFeet scores are significantly higher in making the user feel connected to their teammates. Additionally, the dummy exercises yield a much higher score when it comes to making the user aware of having to keep distance and in making it more difficult to keep that distance.

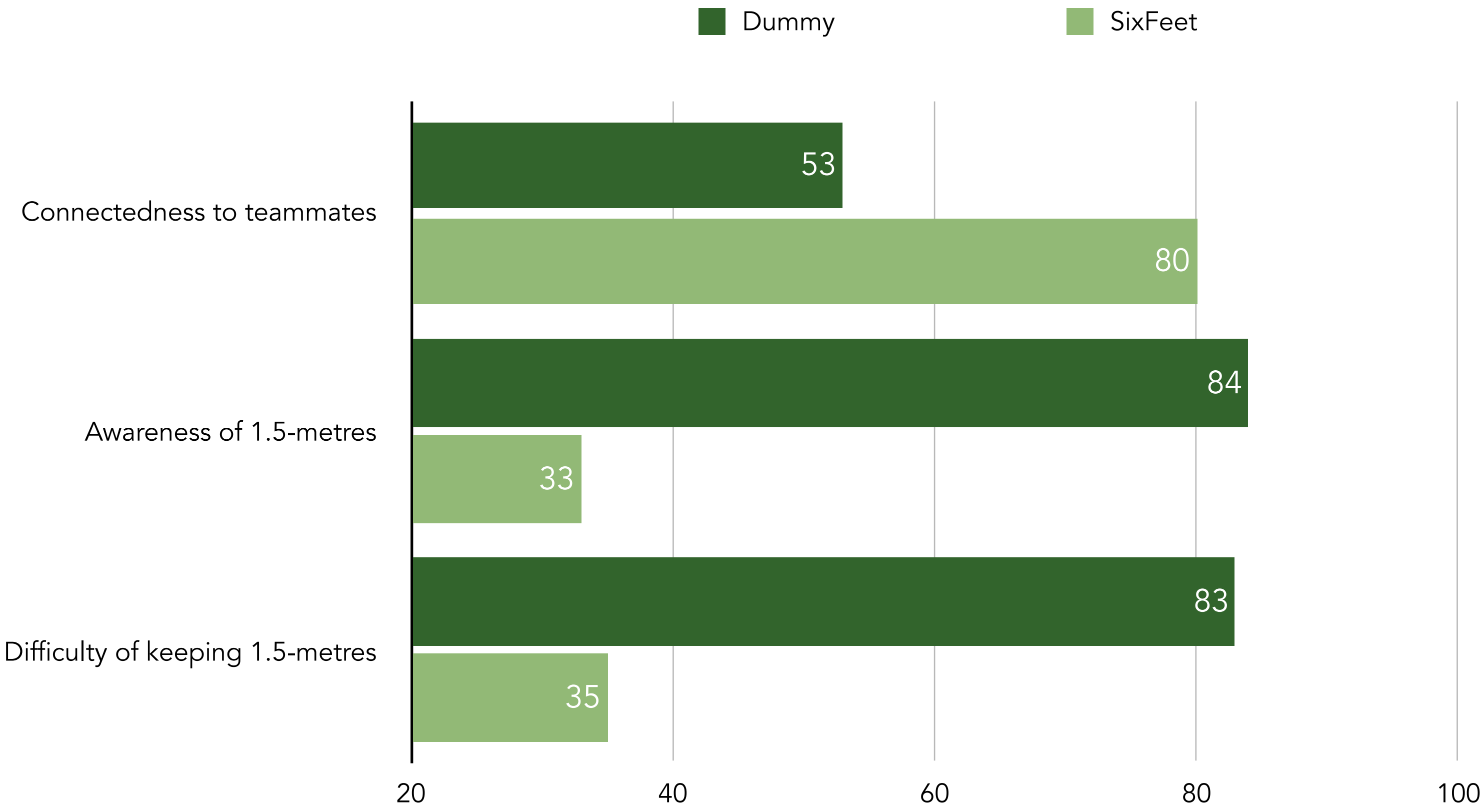

Figure 29: Total scores of immersion-related questions

Using the non-parametric Spearman's correlation test, the correlation between these elements and the perceived enjoyment score from the GEQ, is studied. The correlations are shown in Table 3.

Table 3: Correlations between GEQ score and immersion questions

			Connectedness to teammates	**Awareness of 1.5-metres**	**Difficulty of keeping 1.5 metres**
Spearman's Rho	Enjoyment score	Correlation Coefficient	0,792	-0,799	-0,826

According to the rule of thumb from Rea and Parker [77], all three variables show a strong correlation to the perceived enjoyment score from the GEQ, where the difficulty of keeping 1,5 metres distance arguably has a very strong influence on the perceived enjoyment of the exercises.

8.2.1.5.Informal interviews, remarks and observations

During and after each session, some remarks and conversations were made about the experience of the exercises, by both the users and the trainers and coaches. This subsection presents the main findings from those remarks and conversations. This does not include any remarks about the technical functionality of the prototype, these are included in the next subsection.

Firstly, multiple participants commented that the dummy exercises felt more exhausting and tiring. One participant accredited this specifically to the exercises being less fun, while other participants simply noted that the dummy exercises were more demanding. This was especially true for exercise 2, where players are slaloming after each other.

During the second day of user testing, a player commented that the slaloming exercise was frustrating as the person before her was moving at a lower speed. This meant she had to constantly reduce her speed and had to be mindful of keeping the correct distance. This is also clearly visible from the drone footage, where the player can be seen within a range from 1.5 to 2.5 meters from the player before her, constantly having to slow down.

As for the SixFeet exercises, a few players pointed out that they preferred exercise 2, where the two players outside the circle sometimes have to switch into the circle. One player pointed out that this exercise felt the most as teamwork, as you can come back as either blue or red. It also introduces an extra surprise element where you have to pay attention really well as to when you have to return back into the circle and which colour you are playing. Players were also yelling the colour to each other as they switched positions to help each other.

Furthermore, the trainers commented that the SixFeet exercises effectively combine multiple training goals and skills. According to the trainers, this interactivity and multi-disciplinarily is overall hard to achieve in exercises, but even more so when there is a social-distancing restriction. One trainer made the suggestion to add a helping guide to correctly position and set up the nodes, as this can be quite difficult to estimate without an aerial overview.

8.2.2.Technical Evaluation

Due to unforeseen circumstances, it was not possible to record the first four sessions. The drone was under the constant attack of an aggressive, territorial bird. As the drone footage is necessary for the technical evaluation part of the evaluation, another session at a different hockey club was arranged. Due to time restrictions, only two exercises of each variant could be recorded. Additionally, the participants of this session were demographically very different to the participants of the previous sessions. This, however, revealed some interesting differences and observations that will be discussed in detail in the following sections.

8.2.2.1.Breaches of 1.5-metres rule

All footage that was collected with the drone on the second day of user testing is analyzed frame by frame for any breaches of the 1.5-metres rule. This footage is used to count all occurrences for each individual exercise. This yields the following results:

- SixFeet exercise 1: No breaches
- SixFeet exercise 2: No breaches
- Dummy exercise 1: No breaches
- Dummy exercise 2: 2 breaches. Two players are virtually constantly within a range of 1.5-2.5 meters of each other.

So overall, there were no breaches for the SixFeet exercises and two breaches for the dummy exercises, for the exercises that were reviewed by aerial footage.

8.2.2.2.Informal interviews, remarks and observations

The lights were not always very visible, depending on the position of the player in relation to the station lighting up and the external lighting conditions. This caused for a disruptive effect, where players sometimes took seconds to find the next station. It also caused some players to slightly walk up to the middle of the playing field to get a better overview of all the stations. One participant suggested to add sound to the stations, that can help to locate and identify the next station easier.

Secondly, the method to evaluate the number of close contact moments is arguably not very accurate. While there is a reference measuring tape in frame, this reference constantly changes due to small vertical movements of the drone. In addition, the centre points of the players are used as a measuring point, however, it can be argued that this is not an accurate measuring point.

In addition, due to technical malfunctions, the lights sometimes did not display the correct colour, but rather a sort of 'disco' effect, where multiple colors were flashing at the same time. These issues created some frustrations amongst the participants sometimes, as they had to wait for the station to get repaired again. Repairing, however, was mostly a quick process as a firm thump on the lid of the station usually repaired the light. It did, however, require the game to be put on hold sometimes.

Furthermore, activating the stations was not always a smooth process. As the distance sensors require both transducers to be 'covered' in order to register a player, some situations arose where when a player turns around a station quickly, this is not the case. In these situations, players either held their sticks in front of the sensor or turned around the station once more. This too, caused for a minor, yet disruptive effect of the exercise, especially when for some players this occurred a few times after each other.

Additionally, the speed in which players attempted to complete the exercise greatly dictated how straight their walking lines were. The faster players were more often making mistakes in their running lines, by not running straight through the middle, but rather following the stations. The senior male participants tended to complete the exercises more carelessly, valuing speed over precision. This sometimes caused balls to disappear out of the circle where the part of the exercise had to be halted to retrieve the ball. In addition, this sometimes created situations where players almost came into close contact. The girls who participated in the second day completed the exercises more carefully and precise. They were generally also quicker to understand the exercises.

In addition, the setup in which the stations are positioned is of great importance, as ill-positioned nodes can cause for breaches of the 1.5-metres rule that are not caused by the algorithm.

Furthermore, the parasol bases seemed to perform well. Not many balls hit the stations in general, but in the few cases they did, the parasol bases successfully bounced the balls away from the stations.

8.2.3.Discussion

There were a few practical elements during the evaluation phase, that might have impacted the outcomes of the evaluation phase. An overview of this is given below.

Firstly, as explained earlier, a bird on the first day of user testing prevented the recording of any drone footage. Not only does this make it impossible check for 1.5-metres breaches, but the drone footage is also useful for observations. It would have been nice to validate the functionality of the algorithm more, and to use some of the footage to analyse the behaviour of the players during the exercises.

Secondly, the method to evaluate the number of close contact moments is arguably not very accurate. While there is a reference measuring tape in frame, this reference constantly changes due to small vertical movements of the drone. In addition, the centre points of the players are used as a measuring point, however, it can be argued that this is not an accurate measuring point.

Thirdly, the configuration of the nodes during the second day was not perfect. The user testing session on the second day was somewhat hectic, as it had to be quickly arranged due to the unfortunate events with the bird during the first day. During the setup of the system, there was a light spray for a few minutes, which made the process even more hasted as neither the drone and the system are waterproof. As there was not too much time left, the exercises were started immediately after, without first verifying the position of the stations once more.

Furthermore, as time was so limited, it was not possible to record three exercises of each type, rather only two SixFeet exercises and two dummy exercises. This is especially unfortunate as this is the only recorded session, and therefore no conclusion can be made on the amount of contact moments between players for these exercises.

Lastly, presumably due to the rain on the second day, one of the nodes broke midway an exercise. The distance sensor constantly registered a player, even when there was none. This did not majorly impact the exercise, as when this node was selected, it immediately activated causing the system to calculate a new node immediately. Therefore, the participants did not really notice this. It did, however, make the playing field smaller.

9. Discussion and Future Work

The results, as mentioned in the previous section, show a clear and significantly more positive outcome for nearly all elements for which SixFeet was compared to alternative 1.5-metres distance exercises. As experts and trainers had mentioned beforehand that while these alternative 1.5-metres exercises are representative of the actual situation that teams find themselves in during social distancing dictated training sessions, they are generally not perceived as the most interesting or useful from trainers' and players' perspectives. Therefore, the results from the user testing of the SixFeet system versus these alternative exercises do not come as completely unexpected.

However, while the algorithm in itself allows for dynamic but 'corona-safe' training, this does not make it meaningful in a sport-specific context yet. To that end, this graduation project aimed to develop exercises that showcase the potential of SixFeet as a tool for these meaningful and sport-specific applications. To evaluate just how meaningful these exercises were, they were compared to reasonable and comparable 1.5-metres exercises, that were not externally mediated by SixFeet or any other system. Designing these alternative 1.5-metre exercises with the requirements of being representative and comparable to the exercises developed for SixFeet was challenging. Together with hockey experts, a set of exercises were derived that follow these two requirements as closely as possible.

In addition, it is important to note that the exercises were specifically designed for the participants of the first user testing day, the senior male hockey teams. As the second day of user testing featured a completely demographically different group, the exercises might not have been as meaningful or applicable to this group.

Yet, it can be argued that the comparison of these exercises to SixFeet is unjust, as the alternative exercises are inherently less meaningful in the sense they are unable and limited in addressing training goals in the way SixFeet can. This causes a polarizing difference in the user testing results, which could explain the large variation in the overall score between the SixFeet and alternative exercises. Conversely, that is the very situation that this research aimed to achieve and highlight, as ideally, SixFeet would greatly outperforms the alternative training methods by being more meaningful and enjoyable.

While several measures and precautions were taken to ensure unbiased questionnaire answers, some form of bias cannot be ruled out. Despite the sometimes obvious deficits of the system, that at times caused some frustrations, users seemed to always respond significantly more positive towards SixFeet as opposed to the alternative exercises.

In addition, the evaluation of this graduation project took place during a time where the social distancing measures are far behind in time. This might cause participants to be less accustomed to keeping and having to keep distance. This might cause players to be less wary of keeping distance and might cause players to find it more difficult to place these exercise in the context of being played during periods of social distancing. This could explain a lower score towards the dummy exercises, and more frequent breaches of the 1.5 meters rule than representative to a 'real' situation, where players would be more wary of keeping the distance.

However, players did indicate that maintaining distance using the SixFeet system was much easier than without the system. Moreover, there is a strong correlation with the overall perceived enjoyment of the exercises, where the SixFeet exercises score much higher as a result of this. One of the participants explicitly pointed out that having to actively remember to keep distance is distracting from the exercise itself.

Although in the technical evaluation, there were no occurrences of breaches of the 1.5-metres rule for the SixFeet exercises, some of this can be accredited to sheer luck. Due to the sometimes poorly visible lights, players sometimes tended to walk to the middle of the field, to get a better overview of all the lights. As a result of timing and different walking lines, no breaches occurred in these situations. Additionally, sometimes user errors occur where players run to the wrong station, or do not run in straight lines but rather walk via other stations.

Additionally, the premise of SixFeet being 'corona-safe' is arguably questionable. While 'six feet', or any other pre-determined distance, is largely associated with a safe distance in which the virus cannot be transmitted, this is, in reality, dependent on many external factors. Therefore, while SixFeet is deemed as 'corona-safe', it should not completely be regarded as such, rather as a tool to ease the transitions of periods of lockdown or as a system that provides some more depth and safeguard to existing training sessions during lockdowns.

While at present, the coronavirus is likely to remain part of our reality for the foreseeable future, the system can also prove valuable outside the scope of corona. Both trainers and participants have commented on the value of the exercises developed for SixFeet, but also the potential of the system in terms of designing exercises, irregardless of the smart-allocation algorithm.

As this Graduation Project merely demonstrates the sport-specific potential of SixFeet for field hockey, future research could expand into the realm of other sports. While the prototype served its purpose for this project, it is recommended to discover the possibilities of applying the SixFeet system to existing system architectures, as this could make for a more reliable and representative experience. In addition, working with an existing system architecture could allow for an easier rollout of the system to players, so that when the next period of social distancing comes, SixFeet could be used as an effective tool to provide alternative, yet meaningful training opportunities.

10. Conclusion

Unfortunately, the coronavirus is likely not going to completely leave us any time soon, constantly holding the threat of new lockdowns and social distancing measures over our heads. This impacts our day to day lives tremendously, and induces many adverse physiological and mental health effects. Finding solutions to ease the transition into these periods and to diminish these negative effects associated with these periods, has therefore been the main objective for the development of SixFeet. This graduation project specifically builds on the existing system of SixFeet, to develop a sport-specific, meaningful application for the 'corona-safe' SixFeet platform.

To this end, the main research question that was set out in the beginning of this graduation project was: "How can the SixFeet platform be used to facilitate meaningful sport-specific training exercises for field hockey?". Aided by the subquestions, this question could be answered through the research through design approach taken throughout this project.

When compared to familiar alternative 'corona-safe' exercises, SixFeet showed great advantages over the 'traditional' 1.5-metres exercises in its ability to be considered enjoyable, effective for training and with that in its ability to provide meaningful training opportunities.

This raises the subquestion that was posed at the start of this project; what is considered meaningful? There is no one answer to this question, rather this question was answered during this study as something that is different to every player and team. A meaningful training should adequately address a desired and specific training goal that is relevant to the individual player, while also being representative of a match-like situation while taking note of the training stage in which the player is in. A meaningful training takes into account a balance between purely training tactics and engaging the players otherwise through a social or competitive element in the exercise. A training is meaningful if it is tailored to the specific needs of a player or a group of players.

The exercises developed with and for SixFeet were evaluated to be more enjoyable, fun and dynamic as opposed to the alternative exercises. In addition, participants as well as trainers indicated that the exercises were useful for reaching their training goals and in preparing for matches, irregardless of the context in which they are performed. The exercises were designed in such a way they can easily be tailored to fit the specific needs of its users. All these elements affirm the definition of meaningful as established throughout this research.

By building on the existing SixFeet platform, and expanding its application to sports, this graduation project contributes to solving the main issue its trying to address; the lack of meaningful and attainable training opportunities during covid, which in itself brings negative externalities such as mental health issues. While this graduation project only considers field hockey, this does not diminish the generalizability of the outcomes of this research, as field hockey is part of the invasion sports family as many other popular team sports. The outcomes of this graduation project can be subsequently be taken as an exit point for future research and development to expand SixFeet into the world of other (invasion) sports.

While the coronavirus is seemingly not going anywhere, SixFeet is here to stay.

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APPENDIX A

```
//Node Code for SixFeet, July 2022
//Code created by Annabelle de Ruiter
//Code uses snippets from https://randomnerdtutorials.com/esp-now-esp32-arduino-ide/

#include <ESP8266WiFi.h>
#include <espnow.h>
#include <Adafruit_NeoPixel.h>

#define RING_PIN 5
#define NUM_LEDS_PER_RING 12
#define BOARD_ID 1  //ID for each board, so receiver knows which board it got a message from

Adafruit_NeoPixel ring = Adafruit_NeoPixel(NUM_LEDS_PER_RING, RING_PIN);

int trigPin = 12;
int echoPin = 14;

uint8_t broadcastAddress9[] = {0x30, 0x83, 0x98, 0xB6, 0x13, 0xDC}; //broadcast address of the master

typedef struct struct_message {
  int id;
  char colour;
} stuct_message;

struct_message incomingReadings;
struct_message outgoingReadings;

const long interval = 100;
unsigned long previousMillis = 0;

char incomingColour;
int incomingID;

int i;

long duration, cm;

bool nodeIsActivated;

void OnDataSent(uint8_t *mac_addr, uint8_t sendStatus) { //callback function for when a message is sent.
  //Serial.print("Last Packet Send Status: ");
  if (sendStatus == 0) {
    //Serial.println("Delivery success");
  }

  else {
    Serial.println("Delivery fail");
  }
}
```

```
void OnDataRecv (uint8_t * mac, uint8_t *incomingData, uint8_t len) { //callback function for when a message is received.
  memcpy (&incomingReadings, incomingData, sizeof(incomingReadings));
  incomingColour = incomingReadings.colour;
  incomingID = incomingReadings.id;
}

void printIncomingReadings() { //prints the incoming message
  //Serial.println("INCOMING READINGS");
  Serial.print("Node: ");
  Serial.print(incomingID);
  Serial.println(incomingColour);
}

void setup() {
  Serial.begin(115200);

  WiFi.mode(WIFI_STA);
  WiFi.disconnect();

  pinMode(trigPin, OUTPUT); //Sets the pins for the distance sensor
  pinMode(echoPin, INPUT);

  ring.begin(); //initializes the LED RING

  if (esp_now_init() != 0) {
    Serial.println ("Error initializing ESP-NOW");
    return;
  }

  esp_now_set_self_role(ESP_NOW_ROLE_COMBO); //sets the role of the node to both sender and receiver

  esp_now_register_send_cb(OnDataSent);

  esp_now_add_peer(broadcastAddress9, ESP_NOW_ROLE_COMBO, 1, NULL, 0); //adds the master as a peer

  esp_now_register_recv_cb(OnDataRecv);
}

void getDistance() { //calculates the distance

  digitalWrite(trigPin, LOW);
  delayMicroseconds(5);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  pinMode(echoPin, INPUT);
  duration = pulseIn(echoPin, HIGH);

  cm = (duration / 2) / 29.1;    // Divide by 29.1 or multiply by 0.0343
}
```

```
void loop() {

  unsigned long currentMillis = millis(); //sets a timer so that the incoming and outgoing messages can be read
reasonably
  if (currentMillis - previousMillis >= interval) {
    previousMillis = currentMillis;

    for (i = 0; i < 12 ; i++) { //if the incoming colour is b, then set the led ring to blue
      if (incomingColour == 'b') {
        ring.setPixelColor(i, ring.Color(0, 0, 255));
        ring.show();
      }
      else if (incomingColour == 'r') { //if the incoming colour is r, then set the led ring to red
        ring.setPixelColor(i, ring.Color(255, 0, 0));
        ring.show();
      }
      else if (incomingColour == 'g') { //if the incoming colour is g, then set the led ring to green
        ring.setPixelColor(i, ring.Color(0, 255, 0));
        ring.show();
      }
      else if (incomingColour == 'x') { //if the incoming colour is x, then turn off the led ring.
        ring.setPixelColor(i, ring.Color(0, 0, 0));
        ring.show();
      }
    }

    getDistance();

    if (cm < 70) { //if the distance is smaller than 70 cm, the node is activated.
      nodeIsActivated = true;
      //Serial.print("activated");
    }
    else if (cm > 70) { //If distance is bigger than 70 cm, the node is not activated.
      nodeIsActivated = false;
    }

    if (nodeIsActivated) { //if node is activated send that it is activated to master
      outgoingReadings.id = BOARD_ID; //sends the id so master knows where message is from
      outgoingReadings.colour = 'a';
      esp_now_send(broadcastAddress9, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
    }
    else { //if not activated, send that it is not activated
      outgoingReadings.id = BOARD_ID;
      outgoingReadings.colour = 'u';
      esp_now_send(broadcastAddress9, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
    }
  }
}
```

APPENDIX B

```
//Master Code for SixFeet, July 2022
//Code created by Annabelle de Ruiter
//Code uses snippets from https://randomnerdtutorials.com/esp-now-esp32-arduino-ide/

#include <ESP8266WiFi.h>
#include <espnow.h>

uint8_t broadcastAddress0[] = {0x30, 0x83, 0x98, 0xB5, 0xBD, 0xAA}; //broadcast addresses for all stations
uint8_t broadcastAddress1[] = {0xA8, 0x48, 0xFA, 0xC0, 0x4D, 0x2B};
uint8_t broadcastAddress2[] = {0xBC, 0xFF, 0x4D, 0x59, 0x9B, 0x92};
uint8_t broadcastAddress3[] = {0x30, 0x83, 0x98, 0xA2, 0xDD, 0xFD};
uint8_t broadcastAddress4[] = {0xA8, 0x48, 0xFA, 0xC0, 0xF9, 0x3D};
uint8_t broadcastAddress5[] = {0xA8, 0x48, 0xFA, 0xC1, 0x4F, 0x04};
uint8_t broadcastAddress6[] = {0x30, 0x83, 0x98, 0xB5, 0x58, 0x8F};
uint8_t broadcastAddress7[] = {0xA8, 0x48, 0xFA, 0xC0, 0xAF, 0x2F};

typedef struct struct_message {
  int id;
  char colour;
} stuct_message;

struct_message incomingReadings;
struct_message outgoingReadings;

const long interval = 100;
unsigned long previousMillis = 0;

char incomingColour;
int incomingID;

char colours;
int node;

bool deliveryFail;

void OnDataSent(uint8_t *mac_addr, uint8_t sendStatus) { //callback function for when message is sent
  // Serial.print("Last Packet Send Status: ");
  if (sendStatus == 0) {
    //Serial.println("Delivery success");
  }

  else {
    //Serial.println("Delivery fail");
    deliveryFail = true;
  }
}

void OnDataRecv (uint8_t * mac, uint8_t *incomingData, uint8_t len) { //callback function for when message is received
  memcpy (&incomingReadings, incomingData, sizeof(incomingReadings));
  if (incomingReadings.colour == 'a') { //if the incoming message says activated ...
    incomingColour = incomingReadings.colour;
    incomingID = int(incomingReadings.id);
    Serial.print(incomingID);
    node = incomingID;
    outgoingReadings.colour = 'x'; //when a message of acitavtion is received, set colour to off.
  }
}
```

```
void printIncomingReadings() { //prints incoming messages
  Serial.println("INCOMING READINGS");
  Serial.print("Node:");
  Serial.print(incomingID);
  Serial.println(incomingColour);
}

void setup() {
  Serial.begin(115200);

  WiFi.mode(WIFI_STA);
  WiFi.disconnect();

  if (esp_now_init() != 0) {
    //Serial.println ("Error initializing ESP-NOW");
    return;
  }

  esp_now_set_self_role(ESP_NOW_ROLE_COMBO); //sets the role to both sender and receiver

  esp_now_register_send_cb(OnDataSent);

  esp_now_add_peer(broadcastAddress0, ESP_NOW_ROLE_COMBO, 1, NULL, 0); //adds all stations as peers
  esp_now_add_peer(broadcastAddress1, ESP_NOW_ROLE_COMBO, 1, NULL, 0);
  esp_now_add_peer(broadcastAddress2, ESP_NOW_ROLE_COMBO, 1, NULL, 0);
  esp_now_add_peer(broadcastAddress3, ESP_NOW_ROLE_COMBO, 1, NULL, 0);
  esp_now_add_peer(broadcastAddress4, ESP_NOW_ROLE_COMBO, 1, NULL, 0);
  esp_now_add_peer(broadcastAddress5, ESP_NOW_ROLE_COMBO, 1, NULL, 0);
  esp_now_add_peer(broadcastAddress6, ESP_NOW_ROLE_COMBO, 1, NULL, 0);
  esp_now_add_peer(broadcastAddress7, ESP_NOW_ROLE_COMBO, 1, NULL, 0);

  esp_now_register_recv_cb(OnDataRecv);
}

void loop() {

  unsigned long currentMillis = millis(); //uses timer to reasonably read and write messages
  if (currentMillis - previousMillis >= interval) {
    previousMillis = currentMillis;

    if (Serial.available() > 0) { //serial reading from processing
      colours = char(Serial.read());
      if (colours == 'r') { //if incoming colour is r, set the outgoing colour to red
        node = int(Serial.read() - 48);//reads the node number from processing
        outgoingReadings.colour = 'r';
      }
      else if (colours == 'b') { //if incoming colour is b, set the outgoing colour to blue
        node = int (Serial.read() - 48);//reads the node number from processing
        outgoingReadings.colour = 'b';
      }
      else if (colours == 'g') { //if incoming colour is g, set the outgoing colour to green
        node = int (Serial.read() - 48);//reads the node number from processing
        outgoingReadings.colour = 'g';
      }
      else if (colours == 'x') { //if incoming colour is x, set the outgoing colour to off
        node = int (Serial.read() - 48);//reads the node number from processing
        outgoingReadings.colour = 'x';
      }
    }
```

```
    if (node == 0) { //if the node is 0 send the message to 0
      esp_now_send(broadcastAddress0, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      if (deliveryFail) { //if message was not delivered succesfully, send it again.
        esp_now_send(broadcastAddress0, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      }
    }
    else if (node == 1) {
      esp_now_send(broadcastAddress1, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      if (deliveryFail) {
        esp_now_send(broadcastAddress1, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      }
    }
    else if ( node == 2) {
      esp_now_send(broadcastAddress2, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      if (deliveryFail) {
        esp_now_send(broadcastAddress2, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      }
    }
    else if (node == 3) {
      esp_now_send(broadcastAddress3, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      if (deliveryFail) {
        esp_now_send(broadcastAddress3, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      }
    }
    else if (node == 4) {
      esp_now_send(broadcastAddress4, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      if (deliveryFail) {
        esp_now_send(broadcastAddress4, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      }
    }
    else if (node == 5) {
      esp_now_send(broadcastAddress5, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      if (deliveryFail) {
        esp_now_send(broadcastAddress5, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      }
    }
    else if (node == 6) {
      esp_now_send(broadcastAddress6, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      if (deliveryFail) {
        esp_now_send(broadcastAddress6, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      }
    }
    else if (node == 7) {
      esp_now_send(broadcastAddress7, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      if (deliveryFail) {
        esp_now_send(broadcastAddress7, (uint8_t*) &outgoingReadings, sizeof(outgoingReadings));
      }
    }
    //printIncomingReadings();
  }
}
```

APPENDIX C

```
//Processing code for Algorithm SixFeet, July 2022
//Code written by Annabelle de Ruiter and Louis van Maurik
//Code based on SixFeet algorithm 2020

import processing.serial.*; // use serial port libraries
Serial myPort;              // make a fresh serial port

int posPlayerRed, posPlayerBlue;
int startPosPlayerRed, startPosPlayerBlue;
int pointsPlayerRed, pointsPlayerBlue;
int numberOfNodes = 8;
int nodeActivated;

int startTime;
int time;
int timesPressed = 0;

boolean playerRedIsMoving, playerBlueIsMoving;
boolean bothNeedNewPos;

ArrayList<Circle> circles;

ArrayList<Integer> OptionsPlayerRed = new ArrayList<Integer>();
ArrayList<Integer> OptionsPlayerBlue = new ArrayList<Integer>();

void setup() {
  size (800, 800);
  background (255);

  circles = new ArrayList<Circle>();
  for (int i = 0; i < numberOfNodes; i++) {
    circles.add(new Circle(i));
  }
  startPosPlayerRed = 1; //gives the start position for player red
  startPosPlayerBlue = 3;//gives the start position for player blue
  posPlayerRed = startPosPlayerRed;
  posPlayerBlue = startPosPlayerBlue;

  playerRedIsMoving = false;
  playerBlueIsMoving = false;

  pointsPlayerRed = 0;
  pointsPlayerBlue = 0;

  println("Available serial ports:");
  for (int i = 0; i<Serial.list().length; i++)
  {
    print("[" + i + "] ");
    println(Serial.list()[i]);
  }
  myPort = new Serial(this, Serial.list()[8], 115200); // open port 0 in the list at 9600 Baud
  frameRate(20);  // delay of 50 ms, 20Hz update

  myPort.write ("r" + (startPosPlayerRed)); //sends message to master to turn on LED of start nodes
  myPort.write ("b" + (startPosPlayerBlue));
}
```

```
void draw () {
  background (255);

  for (int i = 0; i < circles.size(); i++) {
    Circle myCircle = circles.get(i);
    myCircle.display();
  }

  text("Red: " + pointsPlayerRed, 40, 40); //keeps track of number of nodes activated by each player
  text("Blue: " + pointsPlayerBlue, 40, 80);

 // firstMove();

  while (myPort.available()>0) { // when there is incoming serial data
    nodeActivated = (int(myPort.read())-48);
    movePlayer(nodeActivated);    // output data to the text console
  }
}

void mouseReleased () { //if mouse is pressed, turn of all LEDs
  if (mouseButton == LEFT) {
    for (int i=0; i<numberOfNodes; i++) {
      myPort.write ("x" + (i));
      pointsPlayerRed = 0;
      pointsPlayerBlue = 0;
    }
  }
  if (mouseButton == RIGHT) { //if mouse is clicked, the game begins
    myPort.write ("x" + (posPlayerRed));
    myPort.write ("x" + (posPlayerBlue));

    bothNeedNewPos = true;
    movePlayer(nodeActivated);
  }
}

void movePlayer(int initButtonThatWasPressed) {
  int buttonThatWasPressed = initButtonThatWasPressed;
  if (buttonThatWasPressed == posPlayerRed || bothNeedNewPos) {
    int posPlayerRedStart = posPlayerRed;
    if (!playerBlueIsMoving) {
      OptionsPlayerRed.clear();
      for (int i = 0; i < numberOfNodes; i++) {
        boolean EnclosesOtherPlayer = false;

        if ((posPlayerRed + 1 == posPlayerBlue && posPlayerRed + 2 == i) || (posPlayerRed - 1 == posPlayerBlue &&
posPlayerRed - 2 == i)) {
          EnclosesOtherPlayer = true;
        }

        if (i != posPlayerBlue && i != posPlayerRed && !EnclosesOtherPlayer) {
          OptionsPlayerRed.add(i);
        }
      }
      posPlayerRed = OptionsPlayerRed.get(int (random(0, OptionsPlayerRed.size())));
    } else {

 while (posPlayerRedStart == posPlayerRed) {
        posPlayerRed = OptionsPlayerRed.get(int (random(0, OptionsPlayerRed.size())));
      }
```

```
ArrayList calculateOptionsOpponent(int start, int end, int otherPlayerLocation) {

  if (start > end) {
    int tempStart = start;
    start = end;
    end = tempStart;
  }

  ArrayList<Integer> OptionsOpponent = new ArrayList<Integer>();
  for (int i = 0; i < end-start-1; i++) {
    OptionsOpponent.add(start + 1 + i);
  }

  if (!OptionsOpponent.contains(otherPlayerLocation)) {
    ArrayList<Integer> OtherOptionsOpponent = new ArrayList<Integer>();
    for (int i = 0; i < numberOfNodes; i++) {
      if (!OptionsOpponent.contains(i) && i != start && i != end) {
        OtherOptionsOpponent.add(i);
      }
    }
    return OtherOptionsOpponent; //On one side of the invisible running line
  }
  return OptionsOpponent; //On the other side of the invisible running line
}
```

```
class Circle {
  int circleNumber;

  Circle (int initCircleNumber) {
    circleNumber = initCircleNumber;
  }
  void display() {
    stroke(0);

    if (posPlayerRed == circleNumber){
      fill(255,0,0);
    }
    else if (posPlayerBlue == circleNumber){
      fill(0,0,255);
    }
    else {
      fill(255);
    }

    pushMatrix();
    translate(width/2, height/2);
    rotate(2*PI/numberOfNodes * circleNumber);
    ellipse(0, -300, 40, 40);
    fill(0);
    textSize(26);
    text(circleNumber,20,-320);
    popMatrix();
  }
}
```

APPENDIX D

Geef aan in hoeverre u het eens bent met de volgende stellingen.

	Sterk mee oneens	Oneens	Neutraal	Mee eens	Sterk mee eens
De afgelopen 3 oefeningen gaven me een goed gevoel					
Ik ben graaf fysiek actief					
Het doen van deze oefeningen vrolijkt me op					
Ik vind de oefening erg interessant					
Het doen van deze oefeningen geeft me een gevoel van voldoening					
Ik geef mijn volle inzet tijdens het doen van de oefeningen					
Ik vergeet de tijd wanneer ik bezig ben met deze oefeningen					
Ik vergeet de tijd wanneer ik bezig ben met deze oefeningen					
Ik voel me relaxed wanneer ik deze oefeningen doe					
Ik kan mezelf zijn wanneer ik deze oefeningen doe					

Geef aan in hoeverre u het eens bent met de volgende stellingen.
Ik vond de oefeningen ...

	Sterk mee oneens	Oneens	Neutraal	Mee eens	Sterk mee eens
Statisch					
Leuk					
Eentonig					
Saai					
Dynamisch					
Gevarieerd					
Duidelijk					
Interactief					

Geef aan in hoeverre u het eens bent met de volgende stelling.
De afgelopen 3 oefeningen...

	Sterk mee oneens	Oneens	Neutraal	Mee eens	Sterk mee eens
zouden mij helpen in het trainen van coördinatie	○	○	○	○	○
zouden mij helpen in het trainen van kijkgedrag	○	○	○	○	○
zouden mij helpen in het trainen van passnauwkeurigheid	○	○	○	○	○
zouden mij helpen in mijn voorbereiding op een wedstrijd	○	○	○	○	○
gaven mij een gevoel van verbondenheid met mijn teamgenoten	○	○	○	○	○
maakten mij bewust van het feit dat ik 1.5 meter afstand moest houden	○	○	○	○	○
maakten het moeilijk om afstand te houden	○	○	○	○	○

(Optioneel) Heeft u nog andere opmerkingen?

APPENDIX E

Please indicate to what extent you agree with the following statements:
- Doing leisure-time physical activities makes me feel good.
- I like being physically active.
- Doing leisure-time physical activities makes me feel energetic and alive.
- Doing leisure-time physical activities cheers me up.
- I think each class is really interesting.
- Doing leisure-time physical activities gives me satisfaction.
- I often give it all I have in leisure-time physical activities.
- I forget the time when I'm doing leisure-time physical activities.
- I feel relaxed when I'm doing leisure-time physical activities.
- During leisure-time physical activity, I feel I can be myself.

Please indicate to what extent you agree with the following statements. I found the exercises to be…
- Static.
- Fun.
- Monotone.
- Boring.
- Dynamic.
- Varied.
- Clear.
- Interactive.

Please indicate to what extent you agree with the following statements. The previous three exercises…
- Could help me train my coordination.
- Could help me train my gaze and viewing behaviour.
- Could help me train my pass accuracy.
- Could help me prepare for a match.
- Gave me a sense of connection with my teammates.
- Made me aware that I had to keep 1.5-metres distance.
- Made it difficult to maintain 1.5-metres distance.

(Optional) Do you have any other remarks?

APPENDIX F

INFORMED CONSENT FORM

Purpose of the research
This research, led by the University of Twente, aims to investigate the value and merits of a novel, interactive sports installation (SixFeet) that lets people exercise in a corona-safe manner.

Research: "SixFeet: corona-safe exercise"
I hereby declare that I am fully informed about the purpose of the research, the research procedure and the relevant research methodology. I have read and I understand the provided information and have had the opportunity to ask questions. I declare to have no (pre-existing) injuries that might put me at increased risk in participating in the experiment. I also declare that I am *not* at risk for severe Covid19 and that I have no symptoms of Covid19 at the moment. I give my consent for the collection of anonymized data, the kind of which has been described in the information brochure. I give my consent for recording audio and video for research and evaluation purposes.

Any (video) data will solely be accessible to researchers affiliated with this research and will never be made public. None of the research data will be used for promotional purposes without explicit consent. All data will be treated and stored according to the rules and regulations of the GDPR. All data will be stored for a minimum of 10 years, conform the NVSU-guideline. You have the 'right to be forgotten', which means that you can request your data to be erased from the research database after participation.

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost.

Date:

Full name:

Signature:

....

Principal investigators:
Annabelle de Ruiter[1], Dees Postma[2]

[1]University of Twente | Electrical Engineering Mathematics & Computer Science | Creative Technology
[2]University of Twente | Electrical Engineering Mathematics & Computer Science | Human Media Interaction

Contact information
If you have any questions concerning this research, please contact Annabelle de Ruiter (a.r.deruiter@student.utwente.nl), any of the researchers on site or the secretary of the Ethics Committee (ethicscommittee-cis@utwente.nl). The Ethics Committee is composed of highly trained research-professionals affiliated with the University of Twente. The Ethics Committee is available for any questions or complaints you might have regarding the research.

APPENDIX G

SIXFEET

Information Brochure Testing and Interview

June 9, 2022

Purpose of the research

In the proposed research, physical activity will be challenged and tested in the form of a field hockey training. The purpose of the research is to gain more information about how the system is being perceived. For example, the amount of enjoyment that is experienced.

Procedure

The procedure consists of questionnaires and physical activity. The researcher will set up the system, and explain everything to the participants.
First, participants take place in variant 1 of training. This will take about 15 minutes. After that participants are asked to complete a short questionnaire. After that, the second variant of the physical activity starts. This takes about 15 mintues as well. After this session is completed, participants are once more asked to complete a short questionnaire.
The physical activity consists of having to run from point to point in several curated sport-specific training exercises. Four participants will be playing the game at a time.

Methodology

Most data will be collected using (video)cameras set up around the field, and a drone (DJI Mavic 2 Zoom), hovering 15 meters at a 90 degree angle above the field. The system will also collect data from the distance sensors that are integrated in the game. All (video) data will be analysed and reviewed.

Participation

Participation is voluntary. Participants will be asked to play the game, which will be explained further on site. During and after playing, participants will be asked to answer questions.
For participation in the experiment it is important that your physical condition is not at risk for any injuries caused by running.

Data collection

During the research, video data will be collected from the game, and the data from the system of SixFeet. This data consists of the amount of points that have been achieved, and the data from the sensors.
Any (video) data will solely be accessible to researchers affiliated with this research and will never be made public. None of the research data will be used for promotional purposes without explicit consent.

Additional information and questions

For additional information and any other questions, please contact **Annabelle de Ruiter** (a.r.deruiter@student.utwente.nl or +31 637011236), any of the researchers on site, Dees Postma (d.b.w.postma@utwente.nl) or the secretary of the Ethics Committee (ethicscommittee-cis@utwente.nl).

APPENDIX H

Participant	Cycle	Type	GEQ1	GEQ2	GEQ3	GEQ4	GEQ5	GEQ6	GEQ7	GEQ8	GEQ9	GEQ10	GEQScore	Statisch	Leuk	Eentonig	Saai	Dynamisch	Gevarieerd	Duidelijk	Interactief	Coordinatie	Kijkgedrag	Passnauwkeurigheid	Voorbereiden	Verbondenheid	Bewust	Moeilijk
1	1	1	2	4	1	2	2	3	2		3	2	21	5	2	4	4	2	1	3	2	2	3	3	1	3	2	4
2	1	1	1	3	3	1	2	3	2		1	3	19	4	2	5	5	1	2	3	1	1	1	1	3	2	5	4
3	1	1	3	4	2	2	2	2	3		4	3	25	4	2	4	4	3	2	2	1	2	3	3	2	4	4	5
4	1	1	3	4	3	2	3	4	3	3	4	4	30	5	3	4	4	3	2	4	2	3	3	4	3	4	4	4
1	1	2	3	4	4	3	5	5	3		3	4	34	2	4	1	2	5	4	4	4	5	3	4	4	3	1	2
2	1	2	4	3	4	5	4	4	3		4	4	35	2	4	1	2	5	4	3	4	4	5	4	3	3	1	2
3	1	2	4	4	4	4	4	3	3		2	4	32	2	4	2	2	5	3	3	4	4	5	4	4	4	2	2
4	1	2	4	4	4	4	4	4	4	4	3	4	35	2	4	2	4	3	4	3	4	4	4	3	4	4	2	2
5	2	1	3	4	3	2	2	3	2	2	3	4	26	4	2	5	5	2	2	3	2	2	2	3	2	2	3	3
6	2	1	2	5	2	2	2	4	2		3	3	25	4	2	5	4	2	4	4	2	2	2	2	2	2	4	4
7	2	1	2	5	2	2	2	4	3	3	2	4	26	5	2	4	4	2	2	3	2	3	3	3	2	2	4	4
8	2	1	2	5	2	1	3	3	3	3	2	4	25	4	2	4	4	2	2	4	2	2	3	3	3	3	4	3
5	2	2	4	4	3	4	4	4	3	3	3	4	33	2	4	3	3	4	3	3	5	4	5	4	4	4	3	3
6	2	2	4	5	4	4	4	4	3		3	4	35	2	4	2	1	4	4	3	5	4	5	4	4	4	2	2
7	2	2	4	5	4	4	4	4	4	3	3	4	36	5	4	1	1	4	3	3	4	4	4	4	4	4	2	2
8	2	2	4	5	4	4	4	4	3	3	3	4	35	2	4	2	2	4	4	3	4	4	4	4	4	3	2	2
9	3	1	2	5	2	2	2	5	2		4	5	29	4	2	4	4	2	2	2	2	2	2	2	2	3	5	1
10	3	1	2	4	3	2	3	4	3		3	3	27	4	2	4	4	2	2	2	2	4	3	4	4	3	4	4
11	3	1	2	5	2	2	3	4	2	2	3	3	26	4	3	3	3	3	2	3	3	3	3	4	4	3	4	5
12	3	1	3	4	2	2	2	2	1	1	2	3	21	4	2	4	4	2	2	4	3	3	4	4	4	3	5	4
9	3	2	4	5	4	4	4	5	4	4	4	5	39	1	4	1	1	4	3	3	5	4	4	4	4	5	1	1
10	3	2	4	4	4	4	4	4	4		4	4	36	1	4	2	2	4	4	4	5	4	4	4	4	4	1	1
11	3	2	4	5	4	4	4	5	4	4	4	4	38	1	5	2	2	5	4	4	5	4	4	4	5	5	1	2
12	3	2	4	4	4	4	4	4	3	3	4	4	35	1	4	2	2	5	4	4	4	4	4	4	4	4	1	1
13	4	1	3	4	3	2	3	4	3	3	2	4	28	4	3	4	4	3	2	2	2	3	3	4	4	3	5	5
14	4	1	2	5	1	1	1	3	3		2	2	20	3	3	3	3	3	3	5	5	3	3	3	3	3	5	5
15	4	1	2	4	2	1	2	3	2	2	2	3	21	4	2	4	5	2	2	2	2	3	3	3	3	2	4	5
16	4	1	3	5	4	2	2	5	3		3	4	31	4	3	4	3	2	2	2	2	3	3	4	4	3	5	5
13	4	2	4	4	4	4	4	4	4	4	4	4	36	5	5	1	2	5	4	2	4	4	4	4	4	4	1	1
14	4	2	5	5	5	5	5	5	4	4	2	4	40	2	5	1	1	4	3	3	5	5	5	4	4	4	1	1
15	4	2	4	4	4	4	4	4	4	4	4	4	36	2	4	2	2	4	4	4	4	4	4	4	4	4	1	2
16	4	2	5	5	5	4	4	5	4		4	5	41	1	4	2	2	5	4	4	5	4	5	5	5	5	1	1
17	5	1	2	3	2	2	3	3	2	2	2	3	22	4	2	4	5	3	4	4	2	3	2	3	2	2	5	5
18	5	1	2	4	2	2	2	3	3	3	3	3	24	4	2	5	5	2	3	4	2	3	2	3	3	2	4	4
19	5	1	3	5	2	2	2	4	3		3	3	27	4	2	5	5	2	3	4	2	3	2	2	3	2	4	4
20	5	1	2	4	3	2	2	2	2	2	2	3	22	4	2	4	4	3	2	4	2	2	3	3	2	2	4	5
17	5	2	3	3	4	4	4	4	3	3	3	4	32	2	3	2	2	4	3	3	4	4	4	4	4	4	3	2
18	5	2	4	4	4	4	4	4	4	4	4	4	36	2	4	2	2	4	3	3	4	4	5	4	4	4	2	2
19	5	2	4	5	4	4	4	4	4	4	4	4	37	2	4	3	2	5	4	3	5	4	5	4	4	4	3	1
20	5	2	3	4	4	4	3	4	5		2	4	33	2	4	2	2	4	3	2	5	2	4	3	4	4	2	3