Aalto University
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Genre analysis of multiplayer motion games utilizing a large high-resolution display

Bachelor's Thesis

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ABSTRACT OF
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This Bachelor's thesis serves as a survey into multiplayer motion games utilizing a large high-resolution display. These research and game development projects embracing computer graphics and spatial tracking technologies can also be called mixed or augmented reality sport (XR Sport, AR Sport).

A literature review and design space analysis was conducted. Material was initially discovered by searching with several term combinations and by examining the publication history of prolific researchers and laboratories in the field. Primary selection criteria for projects were inclusion of both computer games and exertion elements and a multiplayer game mode as well as utilization of a large high-resolution display.

A design space table was formed based on the gameplay and exercise properties as well as technical and spatial solutions employed by the chosen papers. From the table an interested reader can easily spot sparsely researched combinations of design features. Additionally, it enables discovery of specific types of projects based on their features. The chosen works were categorized into genres and the essential features of each genre were described based on the design space table.

Deriving motivated design directions for future reserach and development projects from the table is briefly demonstrated. Some genres of motion games contained several projects and others only few or none. The reasons for this variance are discussed and ideas for underrepresented but promising game types are presented.

Keywords:	motion games, exergames, active video games, social play, design space analysis
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Tämä kandidaatintyö on katsaus suurikokoista korkearesoluutioista näyttöä hyödyntäviin monen pelaajan liikuntapeleihin. Näitä tietokonegrafiikkaa ja tilallisen seurannan teknologioita hyödyntäviä tutkimushankkeita ja peliprojekteja voi monessa tapauksessa kutsua myös jatketun tai lisätyn todellisuuden urheilupeleiksi (XR Sport, AR Sport).

Työ toteutettiin kirjallisuuskatsauksena ja designavaruusanalyysinä. Aineistoa etsittiin hakusanayhdistelmillä sekä tutkimalla alalla paljon julkaisseiden tutkijoiden ja laboratorioiden julkaisuhistoriaa. Pääasiallisina rajauskriteereinä käytettiin sekä tietokonepelielementtien että fyysisen rasituksen olemassaoloa projektissa, monen pelaajan pelimahdollisuutta sekä suurikokoisen korkearesoluutioisen näytön hyödyntämistä.

Valittujen töiden teknisten, tilallisten, rasituksellisten ja pelillisten ominaisuuksien pohjalta muodostettiin designavaruustaulukko. Kiinnostuneen lukijan on taulukosta helppo havaita liikuntapelityyppejä, joita on tutkittu vasta vähän sekä etsiä ominaisuuksien perusteella tutkimuksia lähempää tarkastelua varten. Valitut työt jaetaan genreihin ja näin muodostettujen liikuntapeligenrejen ominaispiirteet kuvaillaan taulukoitujen ominaisuuksien pohjalta.

Tutkimuksen lopuksi demonstroidaan lyhyesti miten koottua designavaruustaulukkoa lukemalla voi löytää perusteltuja suuntia tutkimus- ja kehitysprojekteille. Liikuntapelien luokittelussa havaittiin runsasta esiintyvyyttä tietyissä genreissä ja vähäistä tai olematonta toisissa. Tämän vaihtelun syitä pohditaan ja sen pohjalta esitetään ideoita lupaavista uusista pelityypeistä.

Avainsanat:	liikuntapelit, aktiiviset videopelit, designavaruusanalyysi
Kieli:	Suomi

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Glossary

HCI, Human-Computer Interaction

GPU, Graphics Processing Unit

FEC, Family Entertainment Center

VR, Virtual Reality

AR, Augmented Reality

HMD, Head-Mounted Display

RQ, Research Question

In this thesis the terms *''motion game'',''exertion game'',''exergame'',''embodied game'',''movement-based game''* and *“active video game”* are used interchangeably.

1 Introduction

This Bachelor's thesis discusses recent development in the field of exergaming, focusing especially on multiplayer games utilizing a large display or wall projection. The study maps 21 recent publications and commercial projects in a table displaying their position on 8 design dimensions.

In the past decades computer gaming and eSports have risen to a popular and widespread global activity. Simultaneously there has been significant technological development of fitness equipment and visual presentation of immersive group exercise classes (Martin-Niedecken & Mekler, 2018). Convergence of these two trends can be observed in the field of exergaming. Successful exergame development requires a holistic view encompassing both trends and adding consideration for social aspects and individual fitness level to achieve positive experiences that can be described by "dual flow" (Sinclair et al., 2007).

Social play inherent in multiplayer gaming and team sports has been shown to increase social connection, togetherness and adherence to exergame programs (Kaos et al., 2019). Thus, motion games with multiple simultaneous players were chosen as the focus of this review.

To survey the current state of multiplayer motion games, this thesis presents a systematic literature review and design space analysis done by searching and selecting articles and collecting them to a design space table, where characteristics and properties of found projects were catalogued. Futhermore, a genre was assigned to each found project and these genres were analyzed based on the found properties of projects in that genre.

As an outcome, the reader can easily refer to the design space table and genre listing for further reading and deeper understanding on the field as a whole, on a single genre of motion games or on a specific project. The visual representation of design options chosen by each project and genre allows for identifying gaps in previous art to guide future design and research work.

1.1 Background

The aspiration for the perfect immersive display system for computing and virtual reality (VR) dates back to the 1960s or even further. An early influential demonstration of building an immersive system is the CAVE. (Cruz-Neira et al., 1993)

The visual fidelity and graphical quality of computer games has been rising due to increased performance of hardware such as graphics processing units (GPU) in computers and gaming consoles (Blythe, 2008). It has been one key factor in the rising popularity of computer games due to the increased immersion and delight that better graphics can provide to the player (Wu et al., 2008).

Alongside graphical fidelity, the variety, richness and quality of computer input methods known and researched has been growing in the field of human-computer interaction (HCI) (Banerjee et al., 2012; Thorpe et al., 2011). This trend includes increasing precision of movement input recognition, which leads to increased immersion (Nijhar et al., 2012). A class of input methods highly relevant to exergaming is usage of physiological data such as heart rate to affect a game, shown among others by Martin-Niedecken, Rogers, et al. (2019).

Simultaneously, smartphone applications for fitness tracking, gamified fitness equipment such as exercise bikes with screens, and technological advancements in group exercise have brought technology and gaming to everyday users. This development may lower the threshold for wellness and sports customers to enter the world of motion games. In the family entertainment center (FEC) industry some companies have added some motion gaming products to their offering (e.g. *Superpark* (2021) and *Hoplop* (2021) in Finland).

Use of large displays and spatial interaction methods in public spaces has been researched by Robbins & Isbister (2014). The interaction phases and attention and motivation factors of a bypasser drawn (or not drawn) to an interactive public display were discussed by Müller et al. (2010). Factors affecting the design of public installations catering to a large continuous flux of visitors were outlined by Parés, Durany, et al. (2005). These factors include learning curve, invasiveness and throughput.

The theoretical foundation of motion gaming knowledge is quite established, having introduced concepts such as “dual flow” (Sinclair et al., 2007) and classification and taxonomies of types and features of motion games (F. 'Floyd'. Mueller et al., 2008) as well as theory about sensor technologies on the body, in equipment and in environment (Fogtmann et al., 2008). More recently, this knowledge has been synthesized to a textbook and a comprehensive framework for social exergames. (F. Mueller et al., 2016; F. ‘Floyd’. Mueller et al., 2017)

Exergaming has seen medical applications such as using it as part of the exercise program in post-stroke rehabilitiation (Rand et al., 2015) or as a complement and additional motivator in a physiotherapeutical setting (Smeddinck et al., 2015).

Early examples of holistically designed motion games in research literature were presented by Hämäläinen et al. (2005) and Nenonen et al. (2007). More recently, motion environments involving jumping on a trampoline, gravity and climbing on vertical surfaces have been explored (Hämäläinen et al., 2015; Kajastila et al., 2016, 2014; Naderi et al., 2018).

Several authors have condensed their learnings into guidelines that can be helpful for practicing designers and researchers alike. F. 'Floyd'. Mueller et al. (2011) present *Exertion Framework* as a holistic design vocabulary to be used in the analysis and design of exertion games. Márquez Segura et al. (2013) focus primarily on the bodily experience over physical effort. Marshall, Mueller, et al. (2016) discuss common exergame and exergame study design pitfalls, stating four critiques of earlier efforts and offering three strategies for designing effective and enjoyable exergames.

Florian Mueller & Isbister (2014) provide a set of ten guidelines for designing movement-based games. Isbister & Mueller (2015) discuss these guidelines in the broader context of HCI. However, Vapaakallio (2020) states that the guidelines are mostly focused on at-home exergames and adapts them for the use-case of a climbing game in an entertainment center. After design and implementation of a game project guided by the initial ruleset, Vapaakallio (2020) presents simplified and more widely applicable *Revised guidelines for (Climbing) Motion Games*.

One of the early notable examples of an exergame enjoying widespread commercial and critical acclaim is *Dance Dance Revolution* (1998), making use of a floor-mounted dance pad. Later, motion controllers for home game consoles such as *Nintendo Wii Fit* (2007), *Playstation Move* (2010) and *Xbox Kinect* (2010) entered the market. With the so-called second wave of consumer virtual reality (VR) devices starting around 2016 some popular virtual reality exercise applications such as *Beat Saber* (2018) have emerged.

Some of the latest products successfully applying the findings of exergaming research to out-of-home fitness and motion experiences include *ValoClimb* (2017), *ValoJump* (2018), *iSquash* (2016), *MultiBall* (2018) and *ExerCube* (2018). Recently, the *International Mixed Reality Sports (XRS) Association* (2020) was established to promote physical activity by combining sports, technology and gaming.

1.2 Research questions and goals

An initial review of literature in the field identified a lack of a recent work collecting a large number and variety of motion game research projects into a single source for convenient meta-analysis.

The immediate and most important research goal of this thesis is to find out where on the design dimensions existing exergame projects stand and which genre they belong to. To fill this gap a design space analysis was conducted, driven by the following research questions (RQ).

- RQ1: What gameplay and exercise properties and design dimensions do large display multiplayer motion games have?
- RQ2: What genres of motion games exist and which properties does each genre have?

The properties and genre memberships should be documented in a format that is very easy to understand and analyze. This allows for finding interesting combinations of design choices that have not been tried yet.

1.3 Scope

Key phrases for scope definition in the title of this thesis are “multiplayer motion games” and “large high-resolution display.” The included works feature a physically strenuous exertion game that multiple players play simultaneously as a social experience. The games use a physically large display such as an over 200cm wide wall projection or over 100cm wide television as their display method. The display is capable of showing high-resolution graphics, minimum criteria being images approximately over 1280 pixels wide and 720 pixels tall.

To more precisely define the scope it is helpful to define some things that do not belong in it. The following covers the most significant omissions.

- Virtual reality exergames utilizing only a head-mounted display (HMD) as a display mechanism are omitted. An example of a project describing such a game is (Cao et al., 2020). The HMD or its wiring often gets in the way of social play and more intense bodily interplay as well as causes safety concerns, which makes these games non-ideal for multiplayer motion gaming.
- Park playgames, lamp- or beep-based sports training methods and other exergames that do not utilize a display (e.g (Ludvigsen et al., 2010), (F. ’Floyd’. Mueller et al., 2010)) are omitted. They include exertion and technology, but lack a display mechanism capable of showing high-resolution imagery. Thus, they are unable to leverage the attraction factor of modern computer graphics.
- Another omission are museum installations and educational installations where the display technology and volume of used space are suitable for multiplayer motion gaming, but they are used only to educate and entertain (e.g. (Lindgren et al., 2014), (Snibbe & Raffle, 2009), (Parés, Carreras, et al., 2005)). This is due to the lack of significant physical exertion being included in the experience.
- Single-player exergames such as those discussed by (Martin-Niedecken, Rogers, et al., 2019) are omitted. They are interesting in their own right but do not include the bodily interplay and social aspects that are part of the core focus of this thesis.
- Stationary or endurance-focused exergames (e.g. (Campbell & Fraser, 2019)) are omitted. This includes exergames played on a treadmill or exercise bike. These games only include a minimal amount of movement within a volume, if at all, and are lacking in limbic activation and diversity of body poses.
- Studies focused only on using motion games for rehabilitation and disease treatment (e.g (Rand et al., 2015)) are omitted. In these projects the focus is on recovering regular bodily functions after a serious health-inhibiting event, which overpowers effects of unconstrained social play.
- Games featuring “small-scale exertion” (e.g. (Sheinin & Gutwin, 2014)) are omitted. These games make use of accumulated tiredness of thumb or fingers via repeated motions performed on a game controller to create tense gameplay moments. However, they do not promote enough full-body motion to realize the physiological effects and health benefits of physical exercise.

The above-defined scope is used to guide selection of projects for inclusion in the design space analysis table and subsequent discussion.

2 Methodology

A systematic search process was conducted to find a comprehensive set of relevant material about the current state of multiplayer motion games for design space analysis. This section outlines search considerations and results found via different avenues, namely search engines and publication histories of researchers and laboratories.

2.1 Search and selection process

The initial methodology chosen for the thesis process was Systematic Literature Review (SLR) as described by Kitchenham & Charters (2007). However, during the process SLR was adapted to allow for including other works by specific authors found during the initial search, which resulted in a methodology more closely resembling semi-systematic review defined by Snyder (2019).

In a relatively sparsely studied field this adaptation made it possible to more quickly include the relevant output of prolific research clusters doing high-quality work, instead of trawling through endless poorly-relevant search results. Admittedly, this makes the review somewhat susceptible to personal biases.

Search results found in the initial search engine keyword search process are documented in section 2.2. Search results found via publication histories of specific research groups, laboratories and people are documented in section 2.3.

Conference proceedings, foundational books and research articles were treated as the most reliable sources. In total, of the 1200 examined search results roughly 150 were selected for further evaluation. Of those 150 papers, 21 passed all the exclusion criteria described in section 1.3 and made it to the final large display multiplayer motion game reference table presented in section 3.1.

2.2 Search engine results

In cases where there were less than 100 results for a specific search term or term combination, all search results were skimmed through at least on title level and also on abstract level if deemed necessary. In case the search outcome was more than 100 results, the first 100 most relevant results based on the search term and search engine algorithm received similar treatment.

In total, 12 search terms and term combinations were tested, resulting in the examination of the titles and/or abstracts of approximately 1200 research papers. Based on this examination, articles that included elements such as high resolution wall display, physical exertion or multiplayer or relevant background information were selected for more thorough review. Search results were sorted by "most cited" or "most relevant."

The engine primarily used for searching was Google Scholar. Some of the search terms were additionally inserted to the search fields of publisher-specific databases such as Elsevier Scopus, ACM Digital Library and IEEE Explore to gain a slightly different set of search results. Reported result counts are from Google Scholar.

Search terms (result count)	**Papers for design space analysis**	**Papers for background and theory**
exertion AND games (79600)	(Martin-Niedecken, 2018) (Rebane et al., 2019)	(F. 'Floyd'. Mueller et al., 2017) (F. Mueller et al., 2016) (F. 'Floyd'. Mueller et al., 2008)
embodied game "wall-sized display" (114)	-	(Banerjee et al., 2012)

Search terms (result count)	Papers for design space analysis	Papers for background and theory
“motion game” (651)	-	(Thorpe et al., 2011) (Nijhar et al., 2012) (Kajastila et al., 2014)
“exertion game” AND “wall size display” (no results)	-	-
“exertion game” AND “wall-sized display” (no results)	-	-
“exertion game” wall size display (74)	-	-
“exertion game” “wall-sized display” (no results)	-	-
“motion game” “wall-sized display” (no results)	-	-
“motion game” wall size display (90)	-	-
wall size display interaction exertion game (24300)	(Toprak et al., 2012) (Florian Mueller et al., 2014) (Moreno et al., 2015) (Marshall, Linehan, et al., 2016)	(Ludvigsen et al., 2010) (Müller et al., 2010) (Márquez Segura et al., 2013)
“motion game” opencv (11)	-	-
“motion game” “computer vision” (75)	(Vapaakallio, 2020)	-

In addition to the above general searches, some papers were found by searching for specific terms in the publication history of a specific conference.

Search terms	Conference	Papers for design space analysis	Papers for background and theory
exergame	CHI PLAY	(Alavesa et al., 2015) (Obiorah et al., 2017)	

2.3 Group, laboratory and researcher search results

Some papers were found by examining publication histories or searching for names of researchers, research groups or laboratories with a clear interest in relevant forms of exergaming and a track record of high-quality work. Below are some notable examples of papers found via this method.

The initial seeding of specific persons and laboratories whose publications to examine further was a result of the initial keyword search process documented in section 2.2.

Persons	**Affiliation**	**Papers for design space analysis**	**Papers for background and theory**
Florian 'Floyd' Mueller and Joe Marshall	*Exertion Games Lab, Monash University, Melbourne, Australia*	(Florian Mueller et al., 2003) (F. 'Floyd'. Mueller et al., 2006) (F. 'Floyd'. Mueller & Gibbs, 2007)	(F. 'Floyd'. Mueller et al., 2008) (F. 'Floyd'. Mueller et al., 2011) (Florian Mueller & Isbister, 2014) (F. Mueller et al., 2016) (Marshall, Mueller, et al., 2016)
Anna Martin-Niedecken	*Zürcher Hochschule der Künste (ZHDK), Zürich, Switzerland*	(Martin-Niedecken, 2018) (Martin-Niedecken, Márquez Segura, et al., 2019)	
Perttu Hämäläinen and Raine Kajastila	*Game Research Group (Media Lab), Aalto University, Helsinki, Finland*	(Lehtonen et al., 2019)	
Katherine Isbister	*University of California Santa Cruz (UCSC), California, United States*	(Isbister et al., 2016)	
Maiken Fogtmann, Mads Møller Jensen, Kaj Grønbæk and Martin Ludvigsen	*Center for Interactive Spaces, Aarhus University, Aarhus, Denmark*	(Jensen & Grønbæk, 2016)	(Ludvigsen et al., 2010) (Fogtmann, 2011) (Fogtmann et al., 2008)
Pascal Landry and Narcis Pares	*Full-Body Interaction Lab, Universitat Pompeu Fabra (UPF), Barcelona, Spain*	(Castañer et al., 2016)	(Parés, Carreras, et al., 2005) (Soler-Adillon et al., 2009) (Landry et al., 2013)

3 Results

A collection of 21 projects featuring a large display multiplayer motion game was formed as a result of the search and selection process. Each selected project was examined in light of the design dimensions presented in section 3.2 and the genres presented in section 3.3.

For each project, *yes/no* values were assigned for each aspect of each design dimension. As a result of the analysis, the design space table presented in section 3.1 was formed. Altogether, it contains eight design dimensions with two to six possible values each. Each of the eight dimensions contains a series of options and many, one or no options might apply to a given project. The method is an adaptation of that utilized by Lakier et al. (2019) and in this thesis the term *dimensions* is used in a significance analogous to the *questions* in the original *Design Space Analysis* method of MacLean et al. (1991).

Additionally, each project was assigned to a game genre, which resulted in table 4. Essential properties of each genre were then determined based on the values for each dimension characteristic of projects in that genre.

3.1 Design space table

The final design space table is shown in figure 1. It includes all selected projects, their genres and their positioning along the various design space dimensions.

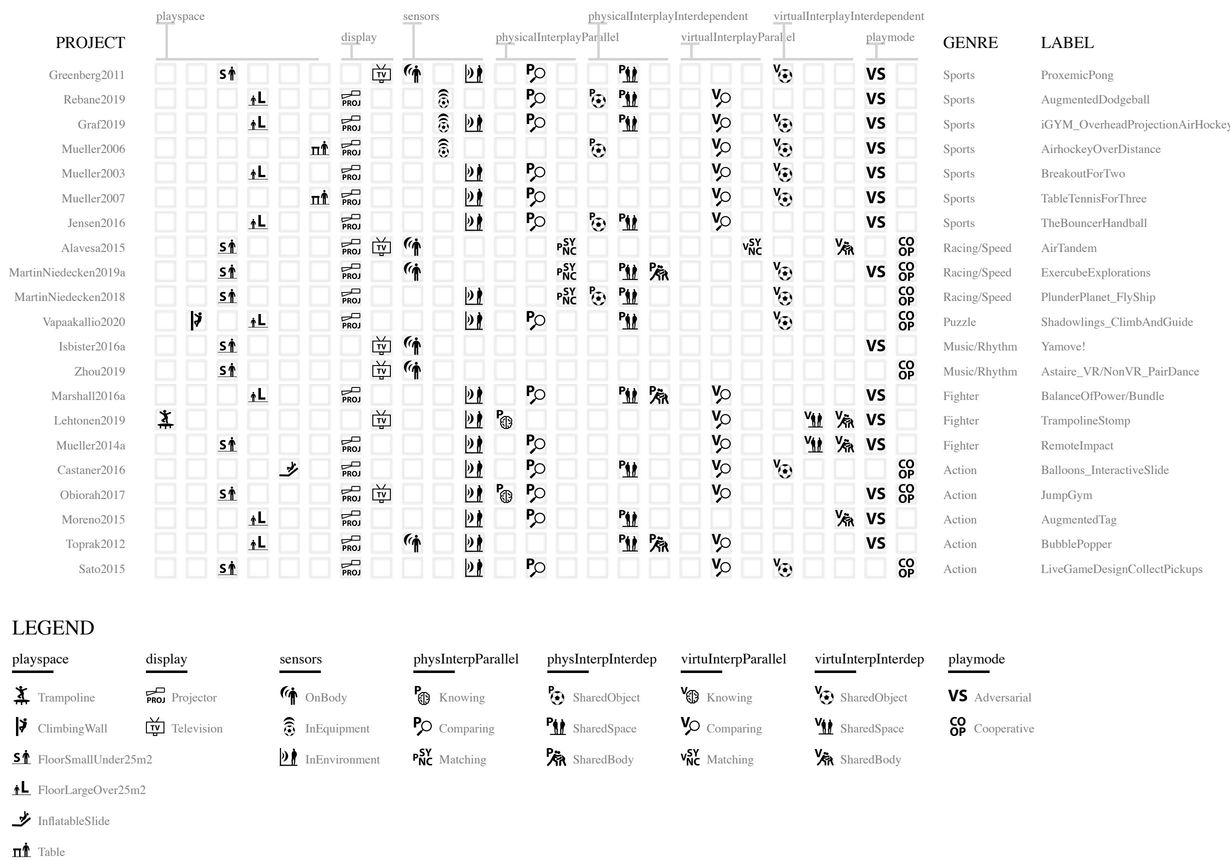

Figure 1: Design dimensions of multiplayer motion games utilizing a large display

Initially, single simple characteristics such usage of a hand controller or a depth camera were considered as the primary design dimensions to investigate. As the understanding of the domain deepened, broader definitions offered by Fogtmann et al. (2008) and F. 'Floyd'. Mueller et al. (2017) were adopted as the basis for the design space analysis, as they are already established in the field.

The categories of the *Bodily Interplay Dimension* (F. 'Floyd'. Mueller et al., 2017) in both the physical and virtual realms were chosen as the primary means of understanding the design space. The main benefit was the capability to simply describe a variety of motion games created from many different premises and utilizing a vast array of display and sensor technologies.

Since one of the core inclusion criteria of this thesis is games utilization of a large display, the only game output mechanism chosen as a design dimension to examine was *displays* in favor of the wider category *actuators* (Fogtmann et al., 2008), which includes e.g. vibration motors and loudspeakers. Playspace size and type *(floor, trampoline, climbing wall, interactive slide, table)* as well as playmode *(adversarial or cooperative)* were considered generally understood dimensions critically affecting the design of most games.

3.2 Multiplayer motion game design dimensions

The design space table figure 1 features a number of design dimensions along which each project is classified. Even if many of the dimension names may be self-explanatory, they are all given more comprehensive definitions in this subsection.

Playspace: A floor-type playspace is considered to be a flat-floor interior space with no obstacles in the given floor dimensions. Dimensions are stated as square meters, cutoff point between small and large floor playspaces being at 25m2 (e.g. 5x5m). The extent of the playspace is calculated based on the whole area where players are likely to move during the game in cases where movement extends significantly beyond a marked play area like in (Rebane et al., 2019).

In some of the examined works the playspace includes non-floor features: games can take place on a *table*, a *trampoline* with guard fences, an indoors *climbing wall* with climbing holds and height up to 3 meters or an inflatable *interactive slide* accomodating at least four players at once, as described by Soler-Adillon et al. (2009).

Display: For a project to be included in figure 1, the usage of a display capable of showing high-resolution graphics (roughly 1280x720 pixels and up) was required. Displays are divided into *televisions* and *projectors*. A key factor is display size, which affects comfortable viewing distance and thus player positioning during the game. The diagonal maximum size of televisions employed by the examined works is roughly 230cm (90inch), which is also the minimum size for projectors. Especially for projectors, low display brightness has a negative effect on the immersivity of the experience.

Sensors: The means by which physical actions of the players are translated to input data affecting the state of the computer game. Sensors are divided into the three categories proposed by Fogtmann et al. (2008): sensors *on the body*, *in equipment* and *in environment*.

An example of sensors on the body is a mobile device or an *HTC Vive* (2016) tracking unit strapped to a limb of a player sending position, rotation or accelerometer data to the game. Sensors in equipment are attached to objects moving freely in the playspace or carried by the player, examples being a hand controller or a ball (Rebane et al., 2019). The added instrumentation provides the game with input such as trigger signals or position and orientation data.

The most commonly utilized sensor in the environment were cameras capturing either color information, depth information or both. In some games the camera system is looking specifically for the shadow of the player (F. 'Floyd'. Mueller et al., 2014; Vapaakallio, 2020). Other sensors in environment include pressure-activated pads or plates such as those utilized by Obiorah et al. (2017) and Martin-Niedecken (2018) (figure 2).

Figure 2: (A) Plunder Planet (Martin-Niedecken, 2018); (B) Shadowlings (Vapaakallio, 2020); (C) Remote Impact (F. 'Floyd'. Mueller et al., 2014); (D) iGYM (Graf et al., 2019); (E) The Bouncer (Jensen & Grønbæk, 2016)

PhysicalInterplayParallel: The *parallel* form of the *physical bodily interplay* presented by F. 'Floyd'. Mueller et al. (2017). Depicts whether the players only *know of* each others' exertion, are able to *compare* themselves with other players during gameplay or are *matching* their movements with other players. Air Tandem (Alavesa et al., 2015, figure 3) is a clear example of *matching* or synchronizing movements and Remote Impact (F. 'Floyd'. Mueller et al., 2014, figure 2) demonstrates how they player might only know of the other players physical exertion but not be able to gain further information of it.

PhysicalInterplayInterdependent: The *interdependent* form of the *physical bodily interplay* presented by F. 'Floyd'. Mueller et al. (2017).

In a game of Shadowlings (Vapaakallio, 2020, figure 2) the game is collaborative and most of the time players are doing their own tasks in physically separate parts of the playspace. However, sometimes their ability to do their task might be affected by the physical location of another player and thus they *share a physical space*. There might be rare accidental moments of physical blocking, but as this is infrequent and not encouraged the game is classified as not having a *physical shared body*.

In The Bouncer (Jensen & Grønbæk, 2016, figure 2) the players take turns interacting with one common physical ball, which is a *physical shared object*. Between throws the path that the next player needs to take to pick up the ball and throw again might be affected by the location of the opposing player, thus they *share the physical space* as well.

VirtualInterplayParallel: The *parallel* form of the *virtual bodily interplay* depicted by F. 'Floyd'. Mueller et al. (2017). As an example in The Bouncer (Jensen & Grønbæk, 2016, figure 2) there are no avatars as such in the virtual realm, only score counters that both players are aware of and able to compare, and thus there is a *virtual parallel interplay* element of *comparing*.

Notable is the omission of projects including an element of *virtual parallel knowing*, where the players would be aware of another player playing, but not e.g. seeing their score and comparing it or being able to match their movement. This is likely due to the fact that the projects are mostly small-scale colocated systems and the surrounding coordination systems that a commercial application would use for reservation and scheduling are not included in the research papers.

VirtualInterplayInterdependent: The *interdependent* form of the *virtual bodily interplay* depicted by F. 'Floyd'. Mueller et al. (2017). In Shadowlings (Vapaakallio, 2020, figure 2), the group of creatures in each game level form a group of *virtual shared objects*. The shadow of each player servers as their avatar in the virtual realm. There is no collision or blocking between the shadows so there is no *virtual shared space* between the avatars.

In iGYM (Graf et al., 2019, figure 2), the projected ball is an obvious *virtual shared object* that both players are able to interact with via their "peripersonal circles," which serve as their avatars in the virtual space. There is no collision between the "peripersonal circles" so there is no *virtual shared body*, but the location of one player's circle might affect the play options of the other player (analogous to screening in basketball) and thus the avatars inhabit a *virtual shared space*.

An interesting case is Airhockey Over a Distance (F. 'Floyd'. Mueller et al., 2006), where the shared concept of a physical puck is split between two remote locations, rendering it both a physical and virtual (conceptual) puck simultaneously.

Playmode: Whether the players are working *cooperatively* as a team to reach a common goal or competing *adversarially* against each other to beat the other player or team.

3.3 Multiplayer motion game genres

Defining clear genres of video games and mixed reality experiences is not a simple task (Foxman et al., 2020; Heintz & Law, 2015; Li & Zhang, 2020). Lucas & Sherry (2004) provide a base selection of genres with sufficient but not excessive detail and Foxman et al. (2020) expand it with genres such as Music/Rhythm to more comprehensively cover the modern video game selection.

In this section motion games are analyzed using the expanded genre division by Foxman et al. (2020), which is as follows: *Action, Adventure, Card/Dice, Classic Board Games, Fantasy/RPG, Fighter, Flight, Music/Rhythm, Puzzle, Quiz/Trivia, Racing/Speed, Shooter, Simulation, Sports, Strategy, Turn-Based Strategy.*

To gain an initial understanding of the genre memberships of the exergame projects examined, each paper was assigned to the best-fitting video game genre based on the descriptions by Lucas & Sherry (2004). The genre that each project was assigned to is shown in figure 1 and the number of members that ended up in each genre is presented in table 4.

Table 4: Number of papers in each game genre

Genre	Action	Adventure	Card/Dice	Classic Board Games	Fantasy/RPG	Fighter
Papers	5	0	0	0	0	3
Genre	Flight	Music/Rhythm	Puzzle	Quiz/Trivia	Racing/Speed	Shooter
Papers	0	2	1	0	3	0
Genre	Simulation	Sports	Strategy	Turn-Based Strategy		
Papers	0	7	0	0		

Action: Action games mostly make use of *projectors* to display their graphics. One of them takes place on the *interactive slide* (Soler-Adillon et al., 2009) while others utilize either a small or large *floor*. Players are equally likely to be *cooperating* or playing *against* one another. Sensors are usually *in the environment*, with the exceptions of JumpGym (Obiorah et al., 2017) that features *pressure-sensitive equipment* and BubblePopper (Toprak et al., 2012) which combines the environment sensor with a hand sensor *on the body*.

The most common game mechanic is collection of items to gain points. Other game mechanics seen are chasing other players (tag) and a side-scrolling endless running game with the goal of avoiding obstacles to run as far as possible. The players *share the physical space*, but there is not much contact. Players are able to observe others players' physical actions, movements of virtual objects and the current score status *(physical parallel comparing, virtual parallel comparing)*.

Music/Rhythm: Music and rhythm games can be played both *cooperatively* and *adversarially*. They use the excitement and positive feelings provided by a musical beat as the main motivator for the players to move themselves. Players in the same space are able to see each other perform dance moves, which enables *physical parallel comparing*.

Fighter: As the name suggests, in all three found fighter games players are *adversarially* competing against each other using contact attacks and thus a *shared body*, which could however be either *physical* or *virtual*, curiously. Sensors are *in the environment*, either distant from the players and out of harms way or embedded in a robust enclosure that can survive repeated impacts.

Ability to aim and time attacks requires awareness of the opponents' movements and thus there is an element of *physical parallel comparing*. During a match players know scores of all players or teams which enables *virtual parallel comparing*. Two games feature a *projected* display next to *floorspace* while one makes use of a *television* and a *trampoline*.

Racing/Speed: The three racing and speed games included feature mostly *cooperative* play in *small floor* playspaces with sensors *on the body* and displaying graphics on a *projector*. In two games players control a shared avatar (bike, flying ship) which serves as a *virtual shared body*, in one they have to hit and dodge shared *virtual objects*.

In Plunder Planet (Martin-Niedecken, 2018) sensors can be alternatively *in equipment* or *in environment*. AirTandem (Alavesa et al., 2015) explicitly rewards synchronization of movement between players, encouraging *physical parallel matching*. Players can benefit from simultaneous choreographies in the other two games as well (Martin-Niedecken, 2018; Martin-Niedecken, Márquez Segura, et al., 2019). Martin-Niedecken, Márquez Segura, et al. (2019) (figure 3) specifically set out to explore social play with their existing racing game, with very interesting results.

Sports: All seven sports games implement a variation of the ever-popular concept of a ball game. The players play *against* each other and the ball is a *shared object* that is either *physical*, *virtual* or both depending on the game. In most games players have opportunities to affect the opponents' options via positioning in the *shared physical space*. In three of the games players are in a physically separate location from their opponent, connected via a videoconference built in to the game system.

The play space is usually a *small or large floor*, but two of the games feature a *table* instead. A large *projected* display makes graphics easy to see from a distance in all but one game. Game input is often registered by sensors *in the environment* that can detect ball hits. Alternatively, a magnetic ball is employed by one project. Planning actions requires awareness of the opponents' movements, which involves *physical parallel comparing* and keeping track of both teams' scores requires *virtual parallel comparing*.

Figure 3: (F) ExerCube Explorations (Martin-Niedecken, Márquez Segura, et al., 2019); (G) Bubble Popper (Toprak et al., 2012); (H) Air Tandem (Alavesa et al., 2015); (J) Table Tennis For Three (F. 'Floyd'. Mueller & Gibbs, 2007); (K) JumpGym (Obiorah et al., 2017)

Puzzle: The sample size of only a single puzzle game does not warrant for very solid conclusions. The features most likely to apply to other puzzle games as well are *shared physical or virtual space*, *shared virtual objects* and *cooperative* play.

By number of projects, *Sports* and *Action* respectively are the most popular genres of multiplayer motion games utilizing a large display. *Fighter* and *Racing/Speed* games are moderately popular and *Music/Rhythm* and *Puzzle* games were also found. No projects were found in any of the following genres: *Adventure, Card/Dice, Classic Board Games, Fantasy/RPG, Flight, Quiz/Trivia, Shooter, Simulation, Strategy, Turn-Based Strategy.*

Assigning motion games to genres revealed some clear patterns in genre popularity. This knowledge enables a reader who plans a future research or development project to consciously make the decision to create a proven and popular type of motion game or to branch out into a less-explored direction.

4 Discussion

In this section grounded future design directions for motion games are derived from the design space table and genre table. Additionally, the limitations of the process employed in this thesis are discussed.

4.1 Design direction from the design space table

To identify underexplored design directions, figure 1 can be scanned for empty or almost empty areas, rows and columns.

Using this method it is immediately evident that the space of multiplayer motion games contains few contact games *(physical shared body)*, few games utilizing non-floor playspaces such as *trampoline*, *climbing wall*, *table* or *inflatable slide*, few games featuring synchronization of movement *(physical parallel matching)*, few games placing sensors *in equipment* and few games placing avatars in a *virtual shared space*.

Another way to find grounded new directions is to explore meaningful connections between different dimensions and genres in the design space table. Synchronizing movements *(physical parallel matching)* seems to go naturally together with *cooperative* games, but what if this link is broken? Result could be a game with where one player tries to synchronize with the other who in turn avoids synchronization, both perhaps indirectly controlling an avatar with a mechanism that has a few seconds of delay to make the game fair and interesting for both.

The table can also be helpful to more quickly repeatedly apply a technique intended for individual games:

pick a project, change one or multiple of the design dimension values and imagine and analyze how that would change the experience.

Choosing (Graf et al., 2019) as an example, the game could be changed to be played in a *small playspace* with the probable result of more hectic and confusing matches. Alternatively, we could change the playspace to a *trampoline*, which would probably make the action very hectic, complicated, fun and interesting but also result in a whole new class of issues around safety and ability to project on a large enough trampoline surface. Changing the objective to gathering appearing balls to a corner as a team would make the play mode *cooperative* and probably help the game be more enjoyable for less competition-driven players.

4.2 Design direction from motion game genres

New grounded research and development directions can be derived by analyzing the genres found and not found within the examined motion game projects. Genres found are *Sports, Action, Fighter, Racing/Speed, Music/Rhythm* and *Puzzle*. Genres not found in the projects are *Adventure, Card/Dice, Classic Board Games, Fantasy/RPG, Flight, Quiz/Trivia, Shooter, Simulation, Strategy* and *Turn-Based Strategy*.

Many of the not-found genres feature long game or match times in contrast to found motion games which are usually short. This is probably caused by the simple fact that exertion makes the players tired and they need rest quicker than somebody playing a video game. However, it could be interesting to design multiplayer exergames around the idea of long-lasting aerobic exercise with the strain of the exertion being similar to going for a slow jog together.

The pace of gameplay is relatively slow in many of these genres compared to the genres found in motion games. Designing games to explicitly feature slow gameplay that still promotes exertion could be very interesting to explore. It could manifest as a card game featuring isometric holds of straining poses between or during turns, with slow *tai chi*-like sequences here and there. The slow pace of gameplay applies to puzzles as well. The one puzzle motion game found within the projects was (Vapaakallio, 2020), which shows the hypothesized principle of isometric holds in the form of having to maintain oneself up on a climbing wall.

Many of the genres not found in this set of motion games rely heavily on an element of fantasy and immersion into an otherworldly space or roleplaying a character as well as discovering the story of the game. This requires time while exergame experiences are usually short due to exertion being physically tiring. Systems built around repeat play could offer a chance to incorporate more elements of character and story development into motion games.

Curiously, no shooter games were found in project table. Seeking for and acquiring targets, aiming and shooting often involves scanning large areas of possible view directions. The limitations of field of view coverage possible to achieve with a display far from players restrict motion games to a suboptimal experience. In addition, there are hurdles in providing a reliably tracked gun-like controller for the players. However, the controller limitation is a mere technical slowdown and field of view coverage could be worked around by designing in specific shooting moments when the player is momentarily almost still and near the display, similar to the game presented by Nenonen et al. (2007).

To open new design avenues via the found genres of motion games we could pick one of the genres, change one or multiple of the parameters and imagine and analyze how the experience would change. For example *racing and speed* games could be adapted to use a large floor playspace instead of a small one. Surprisingly, all of the speed games featured in the table were *cooperative* in contrast to many digital racing games and physical motorsports. Perhaps it would be worth exploring *adversarial* racing motion games.

In a similar vein, *cooperative* variants of the ever-popular sports ball games could be explored or ball games could be transferred to a *trampoline*. Additionally, a worthwhile idea generating tool could be to grab a list of sports not featuring a ball and envision of adaptations of such sports into a multiplayer large display environment: track and field, swimming, skiing, skating, skateboarding, surfing, wind surfing, bowling, darts, climbing, gymnastics and so on.

4.3 Limitations and remarks

As any research work, this thesis has its limitations. The initial discovery process relied heavily on keyword searches in a public research lookup engine and in publisher databases. Due to the nature of these services, the search results obtained using the same keywords will evolve over time and be slightly different at another moment in time.

However, if repeated in the near future an independent researcher should be able to use the same set of search terms and sources to come up with at least a very similar set of source material. Then, that set could be trimmed using the exclusion criteria described in section 1.3 to obtain the works shown in section 3.1.

The chosen dimensions used as basis for the analysis are grounded in earlier theoretical work and can describe aspects of the chosen projects quite comprehensively. Yet still, a different set of perhaps more specific dimensions could have yielded completely different and possibly more accurate insight into the relationships between the projects.

A notable omitted dimension is audio. Music and sound effects have repeatedly been proven to be an important factor in player experience. The main challenge with including audio as an analyzed dimension in this thesis would have been to accurately understand the audio environment of any given project from just a passing mention in a second-hand verbal description and some sparse images. Thus, it was left out of consideration.

The commercial world often moves faster than the academic world. Recent experiments and products by the likes of *MultiBall* (2018) exhibit relevant features and could otherwise have been included in the table, but no published academic work was found that adequately describes them.

This thesis uses written documentation such as research articles and books as its source material. These accounts are written by researchers observing the gameplay situation from the outside. To further explore the experience of the players themselves a qualitative study could be conducted by interviewing players of a variety of motion games using a semi-structured process. This could reveal consumer preferences that do not become evident in a literature review.

5 Conclusion

The aim of this thesis was to present a collection of modern exertion games in a way that enables understanding and comparing their design choices on a variety of dimensions. To that end, research articles and other projects in the field of motion gaming were first searched for and examined. The projects featuring multiplayer gameplay and a large high-resolution display were selected for closer analysis and the search and selection process was documented.

To answer presented research questions, selected projects were collected in a table featuring the design dimensions employed by each project and definitions for each dimension were provided. Additionally, found projects were organized into genres and each genre was analyzed based on the projects. These tables and analyses provide a succint answer to the research questions and a solid base for further research and development.

Methods for using the design space table and the genre table for discovery of future motion game design and research directions were suggested. Finally, the limitations of the employed process and obtained results were described.

References

Alavesa, P., Schmidt, J., Fedosov, A., Byrne, R., & Mueller, F. "Floyd". (2015). Air tandem: A collaborative bodily game exploring interpersonal synchronization. *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play*, 433–438. https://doi.org/10.1145/2793107.2810311

Banerjee, A., Burstyn, J., Girouard, A., & Vertegaal, R. (2012). MultiPoint: Comparing laser and manual pointing as remote input in large display interactions. *International Journal of Human-Computer Studies*, *70*(10), 690–702. https://doi.org/https://doi.org/10.1016/j.ijhcs.2012.05.009

Beat saber. (2018). https://en.wikipedia.org/wiki/Beat_Saber

Blythe, D. (2008). Rise of the graphics processor. *Proceedings of the IEEE*, *96*(5), 761–778. https://doi.org/10.1109/JPROC.2008.917718

Campbell, J., & Fraser, M. (2019). Switching it up: Designing adaptive interfaces for virtual reality exergames. *Proceedings of the 31st European Conference on Cognitive Ergonomics*, 177–184. https://doi.org/10.1145/3335082.3335087

Cao, L., Peng, C., & Dong, Y. (2020). Ellic's exercise class: Promoting physical activities during exergaming with immersive virtual reality. *Virtual Reality*, 1–16. https://doi.org/10.1007/s10055-020-00477-z

Castañer, M., Camerino, O., Landry, P., & Pares, N. (2016). Quality of physical activity of children in exergames. *Int. J. Hum.-Comput. Stud.*, *96*(C), 67–78. https://doi.org/10.1016/j.ijhcs.2016.07.007

Cruz-Neira, C., Sandin, D. J., & DeFanti, T. A. (1993). Surround-screen projection-based virtual reality: The design and implementation of the CAVE. *Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques*, 135–142. https://doi.org/10.1145/166117.166134

Dance dance revolution. (1998). https://www.ddrgame.com/

ExerCube. (2018). https://sphery.ch/exercube/

Fogtmann, M. H. (2011). Designing bodily engaging games: Learning from sports. *Proceedings of the 12th Annual Conference of the New Zealand Chapter of the ACM Special Interest Group on Computer-Human Interaction*, 89–96. https://doi.org/10.1145/2000756.2000768

Fogtmann, M. H., Fritsch, J., & Kortbek, K. J. (2008). Kinesthetic interaction: Revealing the bodily potential in interaction design. *Proceedings of the 20th Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat*, 89–96. https://doi.org/10.1145/1517744.1517770

Foxman, M., Leith, A. P., Beyea, D., Klebig, B., Chen, V. H. H., & Ratan, R. (2020). Virtual reality genres: Comparing preferences in immersive experiences and games. *Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play*, 237–241. https://doi.org/10.1145/3383668.3419881

Graf, R., Benawri, P., Whitesall, A. E., Carichner, D., Li, Z., Nebeling, M., & Kim, H. S. (2019). IGYM: An interactive floor projection system for inclusive exergame environments. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 31–43. https://doi.org/10.1145/3311350.3347161

Hämäläinen, P., Ilmonen, T., Höysniemi, J., Lindholm, M., & Nykänen, A. (2005). Martial arts in artificial reality. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 781–790. https://doi.org/10.1145/1054972.1055081

Hämäläinen, P., Marshall, J., Kajastila, R., Byrne, R., & Mueller, F. "Floyd". (2015). Utilizing gravity in movement-based games and play. *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play*, 67–77. https://doi.org/10.1145/2793107.2793110

Heintz, S., & Law, E. L.-C. (2015). The game genre map: A revised game classification. *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play*, 175–184. https://doi.org/10.1145/2793107.2793123

Hoplop. (2021). https://www.hoplop.fi/en

HTC vive. (2016). https://en.wikipedia.org/wiki/HTC_Vive

International mixed reality sports (XRS) association. (2020). https://xrs.international/

Isbister, K., Márquez Segura, E., Kirkpatrick, S., Chen, X., Salahuddin, S., Cao, G., & Tang, R. (2016). Yamove! A movement synchrony game that choreographs social interaction. *Human Technology*, *12*, 74–102. https://doi.org/10.17011/ht/urn.201605192621

Isbister, K., & Mueller, F. "Floyd". (2015). Guidelines for the design of movement-based games and their relevance to HCI. *Hum.-Comput. Interact.*, *30*(3–4), 366–399. https://doi.org/10.1080/07370024.2014.996647

iSquash. (2016). https://interactivesquash.com/

Jensen, M. M., & Grønbæk, K. (2016). Design strategies for balancing exertion games: A study of three approaches. *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, 936–946. https://doi.org/10.1145/2901790.2901843

Kajastila, R., Holsti, L., & Hämäläinen, P. (2016). The augmented climbing wall: High-exertion proximity interaction on a wall-sized interactive surface. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 758–769. https://doi.org/10.1145/2858036.2858450

Kajastila, R., Holsti, L., & Hämäläinen, P. (2014). Empowering the exercise: A body-controlled trampoline training game. *International Journal of Computer Science in Sport*, *13*(1), 6–23.

Kaos, M. D., Rhodes, R. E., Hämäläinen, P., & Graham, T. C. N. (2019). Social play in an exergame: How the need to belong predicts adherence. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–13. https://doi.org/10.1145/3290605.3300660

Kitchenham, B., & Charters, S. (2007). *Guidelines for performing systematic literature reviews in software engineering*.

Lakier, M., Nacke, L. E., Igarashi, T., & Vogel, D. (2019). Cross-car, multiplayer games for semi-autonomous driving. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 467–480. https://doi.org/10.1145/3311350.3347166

Landry, P., Minsky, J., Castañer, M., Camerino, O., Rodriguez-Arregui, R., Ormo, E., & Pares, N. (2013). Design strategy to stimulate a diversity of motor skills for an exergame addressed to children. *Proceedings of the 12th International Conference on Interaction Design and Children*, 84–91. https://doi.org/10.1145/2485760.2485781

Lehtonen, L., Kaos, M. D., Kajastila, R., Holsti, L., Karsisto, J., Pekkola, S., Vähämäki, J., Vapaakallio, L., & Hämäläinen, P. (2019). Movement empowerment in a multiplayer mixed-reality trampoline game. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 19–29. https://doi.org/10.1145/3311350.3347181

Li, X., & Zhang, B. (2020). A preliminary network analysis on steam game tags: Another way of understanding game genres. *Proceedings of the 23rd International Conference on Academic Mindtrek*, 65–73. https://doi.org/10.1145/3377290.3377300

Lindgren, R., Tscholl, M., & Moshell, J. (2014). *MEteor: Developing physics concepts through body-based interaction with a mixed reality simulation*. 217–220. https://doi.org/10.1119/perc.2013.pr.042

Lucas, K., & Sherry, J. (2004). Sex differences in video game play:a communication-based explanation. *Communication Research - COMMUN RES*, *31*, 499–523. https://doi.org/10.1177/0093650204267930

Ludvigsen, M., Fogtmann, M. H., & Grønbæk, K. (2010). TacTowers: An interactive training equipment for elite athletes. *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, 412–415. https://doi.org/10.1145/1858171.1858250

MacLean, A., Young, R., Bellotti, V., & Moran, T. (1991). Questions, options, and criteria: Elements of design space analysis. *Human-Computer Interaction*, *6*, 201–250. https://doi.org/10.1080/07370024.1991.9667168

Marshall, J., Linehan, C., & Hazzard, A. (2016). Designing brutal multiplayer video games. In *Proceedings of the 2016 CHI conference on human factors in computing systems* (pp. 2669–2680). Association for Computing Machinery. https://doi.org/10.1145/2858036.2858080

Marshall, J., Mueller, F., Benford, S., & Pijnappel, S. (2016). Expanding exertion gaming. *Int. J. Hum.-Comput. Stud.*, *90*(C), 1–13. https://doi.org/10.1016/j.ijhcs.2016.02.003

Martin-Niedecken, A. L. (2018). Designing for bodily interplay: Engaging with the adaptive social exertion game "plunder planet". *Proceedings of the 17th ACM Conference on Interaction Design and Children*, 19–30. https://doi.org/10.1145/3202185.3202740

Martin-Niedecken, A. L., Márquez Segura, E., Rogers, K., Niedecken, S., & Turmo Vidal, L. (2019). Towards socially immersive fitness games: An exploratory evaluation through embodied sketching. *Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*, 525–534. https://doi.org/10.1145/3341215.3356293

Martin-Niedecken, A. L., & Mekler, E. D. (2018). The ExerCube: Participatory design of an immersive fitness game environment. In S. Göbel, A. Garcia-Agundez, T. Tregel, M. Ma, J. Baalsrud Hauge, M. Oliveira, T. Marsh, & P. Caserman (Eds.), *Serious games* (pp. 263–275). Springer International Publishing.

Martin-Niedecken, A. L., Rogers, K., Turmo Vidal, L., Mekler, E. D., & Márquez Segura, E. (2019). ExerCube vs. Personal trainer: Evaluating a holistic, immersive, and adaptive fitness game setup. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–15. https://doi.org/10.1145/3290605.3300318

Márquez Segura, E., Waern, A., Moen, J., & Johansson, C. (2013). The design space of body games: Technological, physical, and social design. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 3365–3374. https://doi.org/10.1145/2470654.2466461

Moreno, A., van Delden, R., Poppe, R., Reidsma, D., & Heylen, D. (2015). Augmenting traditional playground games to enhance game experience. *2015 7th International Conference on Intelligent Technologies for Interactive Entertainment (INTETAIN)*, 140–149.

Mueller, Florian, Agamanolis, S., & Picard, R. (2003). Exertion interfaces: Sports over a distance for social bonding and fun. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 561–568. https://doi.org/10.1145/642611.642709

Mueller, F. 'Floyd'., Cole, L., O'Brien, S., & Walmink, W. (2006). Airhockey over a distance: A networked physical game to support social interactions. *Proceedings of the 2006 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology*, 70–es. https://doi.org/10.1145/1178823.1178906

Mueller, F. 'Floyd'., Edge, D., Vetere, F., Gibbs, M. R., Agamanolis, S., Bongers, B., & Sheridan, J. G. (2011). Designing sports: A framework for exertion games. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2651–2660. https://doi.org/10.1145/1978942.1979330

Mueller, F. 'Floyd'., & Gibbs, M. R. (2007). A physical three-way interactive game based on table tennis. *Proceedings of the 4th Australasian Conference on Interactive Entertainment*.

Mueller, F. 'Floyd'., Gibbs, M. R., & Vetere, F. (2008). Taxonomy of exertion games. *Proceedings of the 20th Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat*, 263–266. https://doi.org/10.1145/1517744.1517772

Mueller, F. 'Floyd'., Gibbs, M. R., Vetere, F., & Edge, D. (2017). Designing for bodily interplay in social exertion games. *ACM Trans. Comput.-Hum. Interact.*, *24*(3). https://doi.org/10.1145/3064938

Mueller, F. 'Floyd'., Gibbs, M., Vetere, F., Agamanolis, S., & Edge, D. (2014). Designing mediated combat play. *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*, 149–156. https://doi.org/10.1145/2540930.2540937

Mueller, F. 'Floyd'., Vetere, F., Gibbs, M. R., Agamanolis, S., & Sheridan, J. (2010). Jogging over a distance: The influence of design in parallel exertion games. *Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games*, 63–68. https://doi.org/10.1145/1836135.1836145

Mueller, Florian, & Isbister, K. (2014). Movement-based game guidelines. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2191–2200. https://doi.org/10.1145/2556288.2557163

Mueller, F., Khot, R. A., Gerling, K., & Mandryk, R. (2016). *Exertion games*. Now Foundations; Trends. https://doi.org/10.1561/1100000041

Mueller, Florian, Stellmach, S., Greenberg, S., Dippon, A., Boll, S., Garner, J., Khot, R., Naseem, A., & Altimira, D. (2014). Proxemics play: Understanding proxemics for designing digital play experiences. *Proceedings of the 2014 Conference on Designing Interactive Systems*, 533–542. https://doi.org/10.1145/2598510.2598532

MultiBall. (2018). https://multi-ball.com

Müller, J., Alt, F., Michelis, D., & Schmidt, A. (2010). Requirements and design space for interactive public displays. *Proceedings of the 18th ACM International Conference on Multimedia*, 1285–1294. https://doi.org/10.1145/1873951.1874203

Naderi, K., Takatalo, J., Lipsanen, J., & Hämäläinen, P. (2018). Computer-aided imagery in sport and exercise: A case study of indoor wall climbing. *Proceedings of the 44th Graphics Interface Conference*, 93–99. https://doi.org/10.20380/GI2018.13

Nenonen, V., Lindblad, A., Häkkinen, V., Laitinen, T., Jouhtio, M., & Hämäläinen, P. (2007). Using heart rate to control an interactive game. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 853–856. https://doi.org/10.1145/1240624.1240752

Nijhar, J., Bianchi-Berthouze, N., & Boguslawski, G. (2012). Does movement recognition precision affect the player experience in exertion games? In A. Camurri & C. Costa (Eds.), *Intelligent technologies for interactive entertainment* (pp. 73–82). Springer Berlin Heidelberg.

Nintendo wii fit. (2007). https://en.wikipedia.org/wiki/Wii_Fit

Obiorah, M., Harburg, E., Bos, M., & Horn, M. (2017). JumpGym: Exploring the impact of a jumping exergame for waiting areas. In *Extended abstracts publication of the annual symposium on computer-human interaction in play* (pp. 13–24). Association for Computing Machinery. https://doi.org/10.1145/3130859.3131428

Parés, N., Carreras, A., Durany, J., Ferrer, J., Freixa, P., Gómez, D., Kruglanski, O., Parés, R., Ribas, J. I., Soler, M., & Sanjurjo, À. (2005). Promotion of creative activity in children with severe autism through visuals in an interactive multisensory environment. *Proceedings of the 2005 Conference on Interaction Design and Children*, 110–116. https://doi.org/10.1145/1109540.1109555

Parés, N., Durany, J., & Carreras, A. (2005). Massive flux design for an interactive water installation: Water games. *Proceedings of the 2005 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology*, 266–269. https://doi.org/10.1145/1178477.1178523

Playstation move. (2010). https://en.wikipedia.org/wiki/PlayStation_Move

Rand, D., Yacoby, A., Weiss, R., Reif, S., Malka, R., Weingarden, H., & Zeilig, G. (2015). Home-based self-training using video-games: Preliminary data from a randomised controlled trial. *2015 International Conference on Virtual Rehabilitation (ICVR)*, 86–91. https://doi.org/10.1109/ICVR.2015.7358588

Rebane, K., Hörnmark, D., Shijo, R., Schewe, T., & Nojima, T. (2019). Augmented dodgeball with double layered balancing. *2019 IEEE Conference on Virtual Reality and 3d User Interfaces (VR)*, 1347–1348. https://doi.org/10.1109/VR.2019.8798062

Robbins, H., & Isbister, K. (2014). Pixel motion:a surveillance camera-enabled public digital game. *Foundations of Digital Games*.

Sheinin, M., & Gutwin, C. (2014). Jelly polo: Increasing richness and competition in sports games using small-scale exertion. *Proceedings of the First ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play*, 367–370. https://doi.org/10.1145/2658537.2662981

Sinclair, J., Hingston, P., & Masek, M. (2007). Considerations for the design of exergames. *Proceedings of the 5th International Conference on Computer Graphics and Interactive Techniques in Australia and Southeast Asia*, 289–295. https://doi.org/10.1145/1321261.1321313

Smeddinck, J. D., Herrlich, M., & Malaka, R. (2015). Exergames for physiotherapy and rehabilitation: A medium-term situated study of motivational aspects and impact on functional reach. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 4143–4146. https://doi.org/10.1145/2702123.2702598

Snibbe, S. S., & Raffle, H. S. (2009). Social immersive media: Pursuing best practices for multi-user interactive camera/projector exhibits. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1447–1456. https://doi.org/10.1145/1518701.1518920

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333–339. https://doi.org/https://doi.org/10.1016/j.jbusres.2019.07.039

Soler-Adillon, J., Ferrer, J., & Parés, N. (2009). A novel approach to interactive playgrounds: The interactive slide project. *Proceedings of the 8th International Conference on Interaction Design and Children*, 131–139. https://doi.org/10.1145/1551788.1551811

Superpark. (2021). https://superpark.fi/en/

Thorpe, A., Ma, M., & Oikonomou, A. (2011). History and alternative game input methods. *2011 16th International Conference on Computer Games (CGAMES)*, 76–93. https://doi.org/10.1109/CGAMES.2011.6000321

Toprak, C. 'Chad'., Platt, J., & Mueller, F. 'Floyd'. (2012). Bubble popper: Considering body contact in games. *Proceedings of the 4th International Conference on Fun and Games*, 97–100. https://doi.org/10.1145/2367616.2367628

ValoClimb. (2017). https://valomotion.com/valoclimb/

ValoJump. (2018). https://valomotion.com/valojump/

Vapaakallio, L. (2020). *Designing climbing games - creating shadowlings for ValoClimb; kiipeilypelien suunnittelu* (p. 34+7) [G2 Pro gradu, diplomityö, Aalto University]. http://urn.fi/URN:NBN:fi:aalto-202006143759

Wu, J., Li, P., & Rao, S. (2008). Why they enjoy virtual game worlds? An empirical investigation. *Journal of Electronic Commerce Research*, *9*.

Xbox kinect. (2010). https://en.wikipedia.org/wiki/Kinect