DESIGN ASPECTS OF MULTIPLAYER EXERGAMES

[TECHNICAL REPORT 2010-571]

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(February, 2010)

Abstract

Exergames combine physical movement and entertainment in order to promote physical activity. *Multiplayer* exergames take advantage of the motivational aspects of group activity by allowing two or more people to play together. Existing research in multiplayer exergames has focused primarily on novel game designs. Currently, there is a lack of understanding on how to support and improve group exercise with exergames. Without a set of design fundamentals, it is difficult to create multiplayer exergames which increase the quality and accessibility of group exercise. This paper synthesizes existing literature into four aspects unique to multiplayer exergames: group formation, play styles, differences in skills and abilities, and quality of exercise. These features make up key design fundamentals specific to multiplayer exergames.

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1. Introduction

National rates of obesity and the average body mass index (BMI) of adults 18 and older have increased over the last two decades. The obesity rate of 25 to 34 year olds rose from 8.5% in 1979 to 20.5% in 2004 [90]. This trend is alarming due to the potential health risks associated with obesity, such as heart disease and stroke [93]. Recent studies suggest that the rise in obesity is partly due to increasingly sedentary lifestyles [48]. Video games, in addition to other media, can contribute to sedentary behaviour and have been linked to increased obesity in adolescents [30]. The current popularity of video games is reflected by the facts that 68% of American heads of households play video games, and that 42% of homes have a video game console [27]. Video games are an interactive form of entertainment, and therefore can incorporate more physical forms of input. Encouraging physical activity is one way in which to combat the rise in obesity.

We define an *exergame* as a video game that requires its players to be physically active. Early examples of exergame equipment include the Atari *Joyboard* and Nintendo *Power Pad* [85] (Figure 1A and B). Several recent exergame systems and peripherals have been commercially successful, for instance Konami's *Dance Dance Revolution* [95] (Figure 1C), Nintendo's *Wii* [69] and *Wii Fit* (Figure 1D), Sony's *EyeToy* [86], and the Fisher-Price *Smart Cycle* [28]. The *Wii MotionPlus* peripheral has recently been released, and Microsoft's *Project Natal* and Sony's *PlayStation motion controller* have been announced, all of which promise to support active forms of gaming.

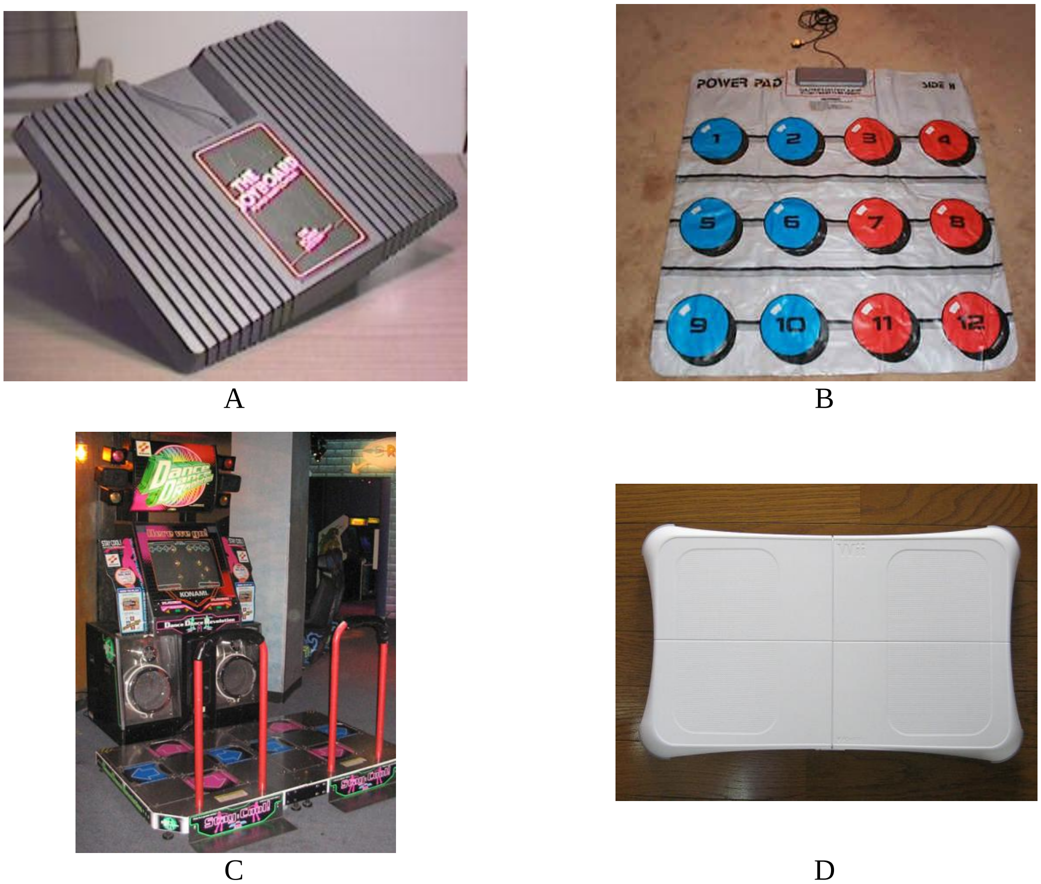

Figure 1: Exergame systems and peripherals. (A) Atari Joyboard, (B) Nintendo Power Pad, (C) Konami's Dance Dance Revolution, (D) Nintendo Wii Fit.

Multiplayer exergames allow two or more people to play together while engaging in physical activity. Sports psychology research shows that grouping can have a positive effect on motivation [3, 33, 36]. Multiplayer exergames can potentially increase exercise motivation and improve the quality of group exercise. For instance, Yim and Graham [106] demonstrate that some of the motivational benefits of group activity can be supported in multiplayer exergames.

Multiplayer exergame research focuses mainly on novel game design concepts, often with few concrete results for designers of exergames. There is currently little understanding of how multiplayer exergames can best support physical activity. This paper examines the design fundamentals specific to multiplayer exergames.

The paper is organized as follows. First, we review theories of motivation and adherence as applied to exercise. These concepts provide an important theoretical grounding for exergames. Sections three to seven review four key design aspects of multiplayer exergames: group formation, play styles, supporting differences in skill and ability, and quality and effectiveness of exercise. Specifically, section three explores research into group exercise and how group activity can be supported and enhanced in exergames; section four examines the various styles of play in multiplayer exergames; section five provides an overview of how differences in peoples' skills and abilities can be supported in multiplayer games; and section six summarizes the quality of exercise provided by existing exergames. Finally, section seven concludes the paper.

2. Behaviour, Motivation and Adherence

Increasingly sedentary behaviour has contributed to rising levels of obesity in adults [48]. Performing physical activity is one approach to reducing obesity. Exergames are designed to encourage physical activity by combining entertainment and exercise; a goal of exergames is therefore to motivate change from sedentary to active behaviour. Thus, it is important for designers of exergames to understand human behaviour and motivation.

This section summarizes three theories of motivation and behavioural change within the context of physical activity. Section 2.1 reviews the Theory of Planned Behaviour, the Transtheoretical Model of Behaviour Change, and self-efficacy. Section 2.2 explores exercise motivation and adherence, and presents several motivators for exercise.

2.1 Behaviour Theory

This subsection explores three theories of human behaviour and their application to exercise. The Theory of Planned Behaviour [1], presented in section 2.1.1, explains the relationship between a person's attitude and behaviour. The Transtheoretical Model of Behaviour Change [74] describes the progress of a person's change in behaviour, and is explored in section 2.1.2. Self-efficacy [5], summarized in section 2.1.3, is a person's belief in her capabilities in performing a certain task.

2.1.1 Theory of Planned Behaviour

Ajzen's *Theory of Planned Behaviour* relates peoples' attitude and behaviour [1]. This theory – an extension of the *Theory of Reasoned Action* [2] – has been used to explore why people lead sedentary versus active lifestyles [66].

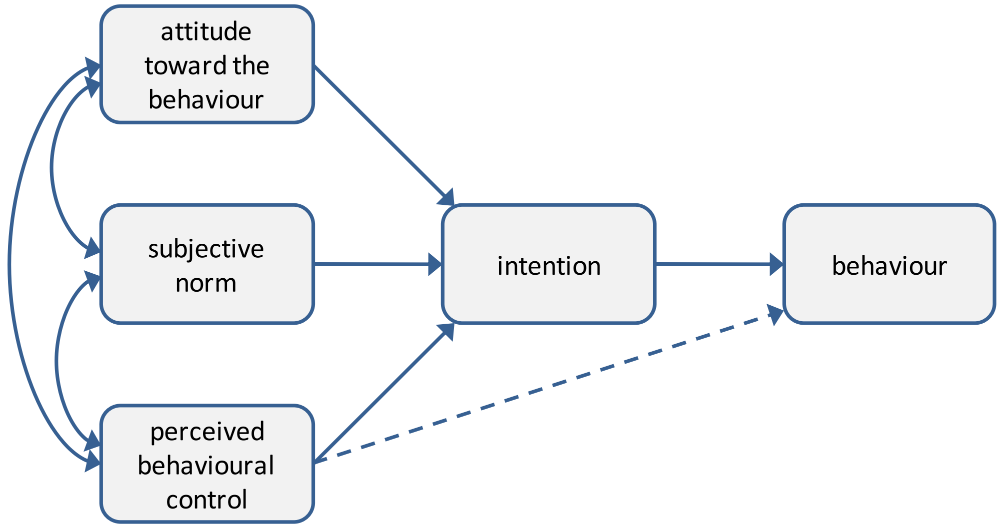

Figure 2: Theory of Planned Behaviour. (Solid lines indicate influence; dashed line indicates that perceived behavioural control and intention can predict behaviour)

The Theory of Planned Behaviour states that human behaviour is determined by intention. A person's intention is influenced by three factors:

- *Attitude toward the behaviour*: the person's favourable or unfavourable view of performing the behaviour (e.g., "jogging regularly would be enjoyable/unpleasant").
- *Subjective norm*: the person's perception of social pressures to perform the behaviour (e.g., "my family thinks jogging would be good/bad for me").
- *Perceived behavioural control*: the person's belief in her ability to carry out the behaviour (e.g., "it will be easy/hard for me to jog regularly").

As shown in Figure 2, all three factors mutually influence a person's behavioural intention. For instance, positive attitude, subjective norm and perceived control will result in a stronger intention to perform the behaviour. Perceived behavioural control, along with intention, can also act as a predictor of behaviour.

Rhodes et al. have found that social support, subjective norm and perceived behavioural control affect intention towards exercise behaviour [78, 80]. These findings support Norman et al.'s conclusion that the Theory of Planned Behaviour is a predictor of exercise intention and future exercise behaviour [66]. In addition to predicting behaviour, the theory can also assist in tailoring exercise interventions for specific populations [79].

The underlying hypothesis of exergames is that if a person has favourable intention toward video game play, this positive intention can be exploited to overcome unfavourable exercise intentions. For example, a person who is anxious about jogging, but confident in playing first-person-shooter games, may be more willing to participate if the two activities are combined. While this hypothesis underlies most work in the exergaming field, it has to date not been directly tested.

2.1.2 Transtheoretical Model of Behaviour Change

The *Transtheoretical Model of Behaviour Change* was introduced by Prochaska and DiClemente to explain the progress of a person's change in behaviour [74]. The model helps predict the success of an intended behavioural change, and can be used to determine why a change in behaviour succeeds or fails.

In their refined model, Prochaska and Velicer [75] include six stages a person moves through during behaviour change: precontemplation, contemplation, preparation, action, maintenance, and termination. Movement through the stages can be either linear or cyclic as a person progresses from precontemplation to termination (see Figure 3). Motivation is based on different factors at each stage, and therefore design of personal interventions should take into account which stage a person has reached for a particular behaviour [75].

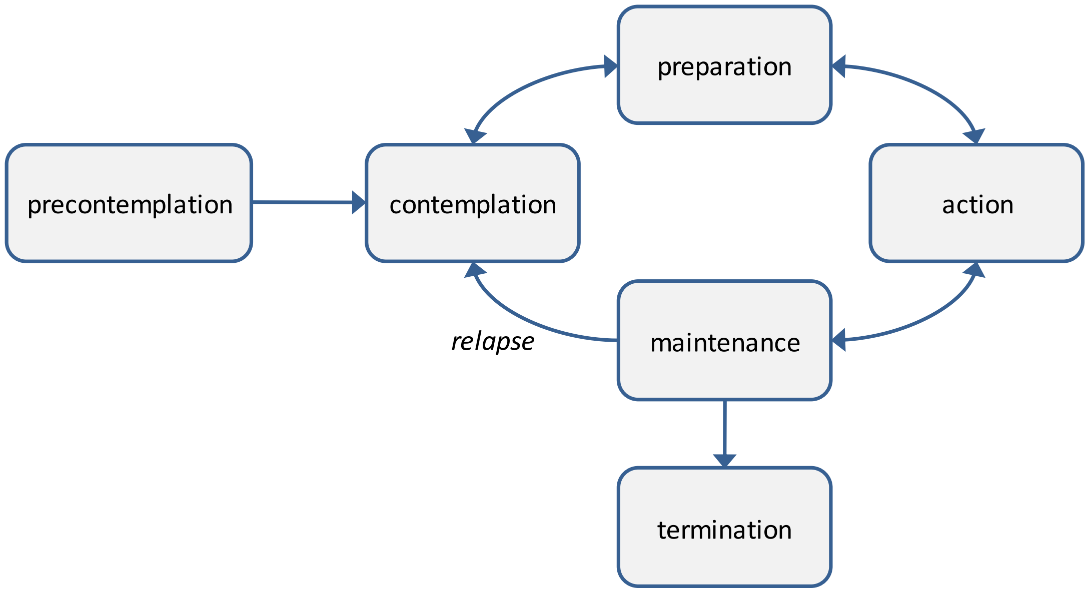

Figure 3: Transtheoretical Model of Behaviour Change – Stages of Change

The Transtheoretical Model includes a series of intervening variables and outcome variables: *decisional balance*, *self-efficacy*, and *temptation* [96]. Decisional balance is a person's weighted measure of the pros and cons of making a change. Self-efficacy – which is explored further in the following subsection – is a person's belief in her ability to make a behavioural change. Finally, temptation is a person's urge toward a habit when encountering challenges. Questionnaire-based measurement of these variables can be used to predict outcome and assist in tailoring interventions.

The Transtheoretical Model can be applied to exercise to measure outcome variables and help in the development of exercise interventions [51, 72]. A person's stage at the start of an exercise intervention affects the progress she will make during treatment [49]. For example, Marcus et al. [50] found that a person's self-efficacy differs at each stage of behaviour change. Interventions therefore should be tailored for different stages of behaviour change in order to address self-efficacy. Similarly, in order to produce a change towards active behaviour, designers of exergames should consider the stage of their target audience. For instance, an exergame for people in the precontemplation stage might be different than a game designed for people in the maintenance stage. Currently, there is little understanding of how multiplayer exergames can support progress through the stages of behaviour change.

Self-efficacy is included as a variable in the Transtheoretical Model of Behaviour Change. Although self-efficacy on its own is not a theory of behavioural change, it is an important factor in health-related changes. Due to its importance in exercise behaviour, self-efficacy is reviewed in the following section.

2.1.3 Self-Efficacy

Self-efficacy is described as "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations" [5]. The concept of self-efficacy was proposed by Bandura as a core aspect of *Social Cognitive Theory* [6]. A person's self-efficacy has an effect on the outcome of her intended goals. For instance, a person with high self-efficacy will approach difficult situations as challenges to be overcome. Conversely, a person who has low self-efficacy will perceive difficult situations as threatening. People who view their capabilities as poor are often more likely to give up, and are more susceptible to stress and depression [6]. Self-efficacy varies for different tasks or domains. For example, a person's jogging self-efficacy may differ from her public speaking self-efficacy.

Self-efficacy has been shown to influence a person's willingness to begin and maintain exercise [53, 83]. For instance, McAuley found that exercise self-efficacy significantly predicts the exercise behaviour of adult males following an exercise intervention [52]. The basic concept of exergames is to exploit high game playing self-efficacy to overcome low exercise self-efficacy.

The following section explores exercise motivation and adherence, and provides a summary of factors contributing to exercise enjoyment.

2.2 Motivation and Adherence

Motivation is the stimulus that causes a person's behaviour [63]. *Adherence* refers to the degree to which a person carries out an action or treatment [34]. Successful exergames must provide both initial motivation to exercise, and support for continued adherence of the exercise program. Section 2.2.1 provides an overview of motivation and adherence in exercise, and section 2.2.2 summarizes related motivating factors.

2.2.1 Exercise Motivation and Adherence

Motivation in sports and exercise can be *intrinsic* or *extrinsic* [22]. Intrinsic motivation originates from a person's expected satisfaction from participating in an activity. Common intrinsic motivators in physical activity include challenge, stimulation, and enjoyment [81]. Extrinsic motivation comes from external sources, for example social pressure, money or awards. Both intrinsic and extrinsic motivators play a role in exercise participation and adherence.

Understanding the motivators for physical activity is important in the design of exergames. By supporting common motivators found in real-world exercise, exergames may be more effective at promoting physical activity. Although it is anticipated that the motivating factors for exercise can transfer to exergames, this has not currently been tested. Additionally, people are often motivated by similar intrinsic factors when playing video games (e.g., challenge, enjoyment) [82, 105]. Multiplayer exergames can therefore exploit both motivation to play games and motivation to exercise. The following section explores several concrete factors that influence motivation and adherence in physical activity.

2.2.2 Factors Influencing Exercise Motivation and Adherence

Motivation and adherence in physical activity are influenced by different personal factors. In their literary examination of exercise adherence, Dominick and Morey [23] propose six categories of adherence factors: demographics, health and biological, cognitive and psychological, behavioural, social, and environmental. Each category includes several factors affecting exercise adherence. For instance, demographic factors include: age, gender, race, education, occupation, marital status, and number of children. This classification illustrates the complexity of influences on a person's willingness to participate in, and adhere to, exercise. Several concrete factors have been shown to influence exercise adherence; these factors are summarized below.

Music

Music has been proposed as a means of increasing exercise enjoyment. For instance, it has been shown that music contributes more to exercise enjoyment than an instructor or a person's self-identity [104].

A review of the psychological and physiological effects of music in exercise reveals three positive outcomes [38]. First, exercise combined with music leads to increased physical output [19, 26, 99]. Second, perceived exertion is decreased with the addition of music to physical activity [10, 89, 99]. Finally, music can have positive influence on emotion and mood at higher levels of exercise intensity [10, 26, 89]. Karageorghis and Terry conclude that properly selected music can enhance enjoyment of and adherence to physical activity [38]. The authors suggest that further reach is required to determine optimal musical characteristics (e.g., tempo, volume, and lyrics) for improved exercise enjoyment.

Instructor

The role of an exercise instructor has been shown to be a valuable factor in motivation and enjoyment. The enthusiasm and support of an instructor have been found to be more important for exercise enjoyment than music [70]. In a survey of fitness class participants, Westcott [101] discovered several important characteristics of fitness instructors: fitness knowledge, teaching skill, enthusiasm, and personal attention. Brehm [11] suggests that an instructor's qualifications, professionalism, experience, and personal attention are key factors in promoting exercise adherence.

Grouping

Participation in group exercise can have a positive influence on exercise motivation and adherence [3, 7, 33]. Several factors related to grouping have been found to influence exercise enjoyment and participation. For example, family and peer support [36], and the compatibility of groups [7], are important motivating factors. Many multiplayer exergames attempt to support the positive aspects of grouping by allowing two or more people to exercise together. A more detailed analysis of grouping is given in section 3.

Person-to-Person Interaction

Interaction between people in sports and exercise occurs in many ways. For instance, in team sports, teammates cooperate while competing against opposing players. Competition typically involves a contest between people, and has been shown to act as a motivating factor in sports and exercise [56]. Cooperation between individuals has also been found to positively influence exercise motivation [3, 36]. Person-to-person interaction in multiplayer exergames is further explored in section 4.

2.3 Analysis

The principles discussed in this section provide a theoretical basis for the design of multiplayer exergames. The Theory of Planned Behaviour explains the link between peoples' attitudes and behaviours. Many multiplayer exergames attempt to promote active behaviour by blending enjoyment of video games with exercise. Self-efficacy explains why a person with low exercise self-efficacy is less willing to participate in physical activity. However, exergames can target a person's high gaming self-efficacy in order to counter-balance low exercise self-efficacy. For instance, Warburton et al. [100] found that combining exercise and games increased peoples' exercise adherence and physical output when compared to traditional training.

Motivation towards particular behaviours varies from person to person. For example, a person with low gaming self-efficacy is less motivated to play games. Therefore, the motivating aspects of exergames are intended for people who enjoy video games.

The underlying goal of exergames is to produce a change from sedentary to active behaviour. The Model of Behaviour Change proposes that behaviour change occurs over a series of stages, and that progression through each stage has different motivating factors. Exergames involving limited physical activity, such as *Wii Sports*, may better address people in the stage of contemplating exercise, whereas exergames designed for physical training, such as *Wii Fitness* and *EA Sports Active*, might be better suited for people in the preparation and action stages of exercise behaviour. Currently there is little research into how multiplayer exergames can support progress through each stage towards active behaviour.

Several of the constructs in the Theory of Planned behaviour and Model of Behaviour Change do overlap in the domain of physical activity [21, 77]. Additionally, the models complement each other. For instance, the Theory of Planned Behaviour has been found to be a good predictor of stage-specific exercise behaviour change within the Transtheoretical Model of Behaviour Change [4, 21, 45].

It is difficult to generalize the results of studies investigating motivation in exergames due to various differences between games (e.g., type of physical activity, intensity and duration of exercise, demographics). For instance, there is no evidence that the positive exercise adherence found with the *GameBike* peripheral [100] carries over to the *EyeToy* [64]. Although existing research illustrates where exergames succeed or fail at promoting exercise, further research would be valuable.

Group activity is an important concept in the design of multiplayer exergames. Promoting group formation and supporting group interaction in exercise and games are further explored in the next two sections.

3. Group Formation

In some settings, grouping has been shown to have a positive influence on exercise participation [3, 33, 36]. The concept underlying many multiplayer exergames is to promote exercise by including the motivation of group activity. This section reviews the findings from exercise psychology on group exercise and group cohesion, and summarizes how grouping has been supported in multiplayer exergames.

3.1 Effectiveness of Group Exercise

In several contexts, adults prefer to exercise in a group rather than alone [33]. For Instance, Burke et al. [13] found that group exercise, outside of a structured class, is the most preferred form of physical activity for university students. *Group cohesion* is a major factor in adherence to group exercise [3, 15, 18, 29, 87]. Group cohesion is described as the "stick togetherness" of a group. More formally, cohesion is defined as "a dynamic process which is reflected in the tendency for a group to stick together and remain united in the pursuit of its goals and objectives" [14]. Carron et al. propose that cohesion is related to individual adherence behaviours in group exercise scenarios [15]. Similar findings have been discovered in female group fitness classes [29, 87]. Factors affecting group cohesion in physical activity include the type of participants, type of exercise, and duration of an exercise program [8]. Other factors shown to influence adherence in group exercise include:

- *Convenience*: real world group exercise typically requires travel to an athletic facility and proper scheduling [11, 23].
- *Body composition*: a person's exercise self-efficacy and perception of her own body influence the willingness to participate [11, 36, 42, 71].

- *Compatibility*: people are more inclined to participate if there is commonality among group members. For example, age [5, 11], fitness level [11], and goals [16].
- *Interaction*: strong interaction and communication among group members is positively correlated to cohesion [16].
- *Social support*: mutual support among group members can influence a person's self-efficacy and perception of fitness capabilities [12]. For instance, Hohepa found that a lack of peer support adversely affects exercise participation in youth [36].
- *Attendance*: group members who are absent less often have a higher attraction to group exercise [87]. Absence from group exercise programs can lead to fears of not being able to catch up [11].
- *Variety of exercise modalities*: group activities involving a range of different exercise can better support people with varying fitness capabilities [23].

Designers of multiplayer exergames should consider factors of grouping in order to better support exercise adherence. Manipulating group dynamics has been proposed as a way of promoting physical activity [18]. However, there is currently a lack of research into how to optimize factors of grouping and their degree of influence on motivation and adherence [8].

Home-based exercise allows a person to exercise alone at home, whereas group-based programs require meeting at a specific location and time (e.g., aerobics class). Several studies have found higher long-term adherence in home-based compared to group-based exercise interventions [23, 42, 71, 76]. The results of these studies illustrate four potential deterrents to adherence in group exercise:

- *Scheduling*: real-world group exercise requires people to meet at a specific time [41, 71, 76].
- *Travel*: group exercise typically occurs outside the home, thus requiring people to travel to a particular location [41, 71, 76].
- *Self-efficacy* and *self-esteem*: social comparisons are possible in group exercise and can result in embarrassment for people with low self-efficacy or self-esteem [42, 76].
- *Financial cost*: group exercise programs may require additional costs such as gym membership fees [76].

Long-term adherence to home-based exercise can be partly attributed to the convenience and flexibility it offers over group-based exercise [9, 40]. However, effective home-based physical activity may require proper supervision and support from fitness professionals [40].

Multiplayer exergames offer some potential solutions to the inconveniences of group exercise while including the motivational aspects of group activity. For instance, networked exergames can allow for home-based physical activity and eliminate the need for scheduling and travel. Existing approaches for supporting grouping in multiplayer exergames are explored in the following subsection.

3.2 Supporting Grouping in Multiplayer Exergames

Multiplayer exergames need to facilitate grouping among players in order to benefit from the positive motivation and adherence found in group exercise. In their exergame design requirements, Yim and Graham [106] include three approaches to support grouping: hide players' fitness levels, reduce barriers to grouping, and actively assist group formation.

Issues of self-esteem have been shown to be a barrier to group exercise [42, 76]. Therefore, multiplayer exergames should avoid revealing player fitness levels in order to minimize feelings of inadequacy [106]. Distributed multiplayer exergames make it possible to hide a person's appearance behind her virtual avatar. For instance, in the Heart Burn [88] exergame, players only see virtual representations of one another. Hiding fitness levels is more challenging in co-located settings, since people play together in the same location. However, several exergames include balancing and scaling mechanism to support play among people with different capabilities; this topic is explored further in section 5.

Allowing friends to play together can have a positive impact of group cohesion. However, many multiplayer video games have divided servers or levelling systems which separate and segregate players (e.g., *World of Warcraft*). This practice makes it difficult for friends to play together and should be avoided in multiplayer exergames [106]. The majority of existing multiplayer exergames are found in academic labs, and have not addressed this problem. However, the balancing mechanisms found is some multiplayer exergames can allow players who might normally be separated to play together (see section 5).

Group cohesion can positively influence exercise adherence [15, 29, 87]. Therefore, multiplayer exergames should actively promote group formation among players [106]. A common approach to encourage grouping in exergames is to include collaborative tasks. For instance, in several multiplayer exergames winning is dependent on players cooperating together [35, 43, 91, 98]. The communication and coordination required between players can have positive influence on group cohesion. Approaches for supporting player cooperation are further explored in section 4.

3.3 Analysis

In many instances, people prefer group exercise to individual physical activity. In general, multiplayer exergames support group activity in an attempt to encourage exercise. Multiplayer exergames also offer greater flexibility than real-world group exercise. For instance, distributed multiplayer exergames can support group-based exercise at home and thus minimize the need to travel.

Several factors have been found to influence group exercise adherence: convenience, body composition, group compatibility, interaction, social support, attendance, and variety of exercise modalities. Manipulating the dynamics of grouping can improve adherence. The importance of these factors on adherence suggests that they should be considered by exergame designers. However, further investigation is required into grouping in exergames.

In order to better support group exercise, multiplayer exergames should hide players’ fitness levels, reduce barriers to group formation, and actively assist players in forming groups. Several exergames include mechanism to address these guidelines. For example, game balancing can reduce potential barriers to grouping, and cooperative goals can encourage group formation. The affects of these approaches in exergames have not been evaluated to date.

4. Play Styles

Allowing people to play and exercise together is a fundamental feature of multiplayer exergames. Different styles of play are possible in exergames and it is important for designers to understand the tradeoffs of each approach. The actions occurring between players of multiplayer exergames can be classified over several dimensions: time, space, and mode of interaction.

Existing multiplayer exergames support two modes of interaction between players: cooperative, or competitive. These modes can occur in different configurations of space (co-located or distributed) and time (synchronous or asynchronous). This section reviews how players may interact with each other in multiplayer exergames.

4.1 Modes of Interaction

The subsections below examine two approaches for supporting interaction among exergame players; section 4.1.1 explores player cooperation, and section 4.1.2 discusses player competition.

4.1.1 Player Cooperation

Cooperation involves players collaborating to achieve a common goal. For example, in *World of Warcraft,* players often form groups to cooperatively defeat an in-game foe. Cooperation has been shown to be a motivational aspect of multiplayer games [24, 65]. Existing multiplayer exergames support either independent or dependent cooperation among players.

Independent Cooperation

Independent cooperation allows players to achieve a shared goal while not requiring players to work together [32]. Success within the game is not dependent on players coordinating.

Figure 4: *Human Pacman* [17]
(center: mobile player; top-right: remote “helper” player)

Independent cooperation can be found in the *Human Pacman* exergame [17]. Players move around the real world while interfacing with an augmented-reality environment using mobile computing devices. The goals of the original *Pacman* arcade game are replicated with players taking the role of Pacmen and Ghosts. Pacmen must collect all the virtual pellets while Ghosts attempt to terminate the Pacmen. Independent cooperation in the game occurs in two cases: between mobile teammates, and between mobile and remote players. Mobile Pacmen can coordinate in order to pass virtual objects to one another. Additionally, each mobile player is supported by a remote “helper” player who is able to see the entire virtual world on her terminal (see Figure 4). A mobile player can gain useful game-state information by coordinating with her helper. The game is easier to win if each mobile player cooperates with teammates and remote players. However, a mobile Pacman player could collect all the virtual pellets without ever interacting with her remote or fellow Pacmen players. This configuration demonstrates the feasibility of independent cooperation in multiplayer exergames.

Independent cooperation supports group collaboration while providing the flexibility of individual play. It is possible that independent cooperation may have poor influence on group cohesion since coordination among players in not required. However, the effect of independent cooperation on motivation in multiplayer exergames has not been studied to date.

Dependent Cooperation

Dependent cooperation requires players to interact in order to achieve a common goal. Success within the game is dependent on all players coordinating their respective actions [32].

A variety of approaches have been used to implement dependent cooperation in multiplayer exergames. For example, *Nautilus* [91] involves players taking the role of a diving bell crew on a mission to save a dolphin stuck under a shipwreck. A group of players perform physical movements in front of a large display with their actions captured by floor sensors (see Figure 5). Speed and direction of the virtual diving bell are controlled by the center of mass of the players, making cooperation essential. A similar approach is found in the *Body-Driven Firemen* exergame [43]; however, computer vision captures player's movements. A group of players must cooperate as a team in order to catch falling virtual-characters (see Figure 6). Players need to move together and form a circle under a character in order to save it. The *Socio-ec(h)o* exergame [98] also involves players performing physical actions together to solve puzzles in a "smart" environment. Players must cooperate to complete a series of body poses and movements in order to advance through each level of the game.

Figure 5: ***Nautilus*** **[91]**

Figure 6: ***Body Driven Firemen*** **[43]**

The *Paranoia Syndrome* [35] exergame is designed to foster cooperation by requiring players to coordinate in order to fight off virtual opponents. Players move around a physical space and use PDAs and physical objects to interface with a virtual game environment. At the beginning of the game, players choose from one of three roles: scientist, technician, doctor. Each player role has unique capabilities. Since winning the game requires skills from each role, player must cooperate in order to win.

The *Frozen Treasure Hunter* exergame [106] was developed to investigate the motivational aspects of group play in exercise games (see Figure 7). Player cooperation is encouraged by having two players (either distributed, or co-located) control a shared avatar. One player steers the avatar using a recumbent bicycle and gamepad, while the other player swats incoming virtual projectiles using a Wii remote. The goal of the game is to collect a series of virtual object as quickly as possible. Success in the game requires dependent cooperation between players. Similarly, *Push'N'Pull* [60] is a two-player distributed exergame involving shared player control.

Players must push or pull their own resistance training device in order to collect on-screen items. Gathering the items requires players to coordinate their physical effort.

Figure 7: *Frozen Treasure Hunter* [106]
(bottom-right: one player biking and one player swatting)

The multiplayer exergames presented above demonstrate that dependent collaboration is possible in multiplayer exergames. As discussed in section 3.1, cohesion, social support and interaction are important factors in group exercise motivation. Multiplayer exergames with dependent cooperation might support these factors better than independent cooperation. For instance, the communication and coordination required in the socio-ec(h)o exergame [98] was found to have a positive influence on group cohesion. Alternatively, the physical contact required between players in some cooperation-dependent exergames may introduce feelings of discomfort. For example, Laasko and Laasko [43] observed that groups of strangers were uncomfortable holding hands together when playing Body-Driven Firemen. To date, the effects of dependent and independent cooperation on group cohesion have not been generalized. Further investigation into cooperation in exergames would provide valuable lessons for designers.

4.1.2 Player Competition

Competition involves a contest between players. In some instances, the enjoyment of competition has been found to be a motivating factor in multiplayer video games [37, 97]. Similarly, competition can motivate participation in sports and exercise [56]. Two forms of competition are supported in existing multiplayer exergames: independent and dependent.

Independent Competition

When competition is independent, a player's in-game actions have no direct effect on the performance of other players. Independent competition in video games is often achieved by having players take turns. For example, in two-player *Ms. Pacman*, players alternate turns while attempting to collect as many points as possible. A player's turn is over once her avatar dies, and the game ends when both players have lost all lives. The player with the most points is declared the winner.

Independent competition can be found in several commercial exergames. For example, *Dance Dance Revolution* (DDR) is a popular dance-simulation game which includes a multiplayer mode [54]. Each player receives points for their ability to perform dance moves in rhythm to music. Since a player's actions only affect her own score, competition among players is independent. Turn-taking is another approach for independent competition. For instance, *XaviX Bowling* [55] is a bowling simulator which supports multiplayer matches. In multiplayer mode, each player takes turns throwing a ball at virtual on-screen pins. Although players compete for the highest score, a player's in-game actions do not affect those of her opponents. Independent turn-taking can also be seen in *Wii Sports* bowling and golf.

The *Heart Burn* [88] exergame allows two players to race their virtual trucks along a track. The first player to cross the finish line is declared the winner. Each player controls the speed of her truck by pedaling a recumbent exercise bicycle. Although players race at the same time, their virtual trucks are able to pass directly through each other without consequence. Competition is independent since a player's in-game actions cannot directly affect the performance of her opponent.

The examples presented above illustrate the feasibility of independent competition in multiplayer exergames. Several popular commercial exergames include independent competition (e.g., DDR, Wii Sports). However, the lack of interactions among players may negatively impact enjoyment [32]. The effect of independent competition on motivation has not been investigated in multiplayer exergames. Further research would help to identify best practices for supporting independent competition in exergames.

Dependent Competition

With dependent competition, a player's in-game actions affect the performance of her opponents. This form of competition is common in traditional competitive games (e.g., football, chess) and multiplayer video games (e.g., *StarCraft*). The baseball, tennis, and boxing exergames in Wii Sports involve dependent competition.

Figure 8: *Breakout for Two* [57]

Figure 9: *Remote Impact* [62]

Mueller et al. have developed numerous multiplayer exergames with dependent competition [57–59, 62]. The aim of these games is to encourage social bonding while promoting physical activity. For example, in *Breakout for Two* [57], two distributed players kick soccer balls at a projected wall display covered with virtual bricks (see Figure 8). Bricks are destroyed once they are hit three times with a ball, and the player who is able to destroy the most bricks is the winner. Competition between players is dependent since one player may destroy a brick before her opponent has the opportunity to do so. A similar approach for dependent competition is used in the *Table Tennis for Three* exergame [59]. Distributed players each use a physical paddle and ball to break virtual bricks on a projected display. The *Airhockey Over a Distance* game allows two distributed people to play air hockey using specialized equipment. Dependent competition is possible since players tactically return or “stall” the puck, similarly to real-world air hockey. *Remote Impact* [62] combines dependent competition with forceful player input. The shadow of a player’s opponent is projected on a screen, and a player is able to kick, punch and ram the padded display (see Figure 9). The more forcefully a player hits her opponent's shadow, the more points she incurs. A player can purposefully dodge or strike her opponent's shadow, making competition dependent.

Figure 10: *Age Invaders* [39]

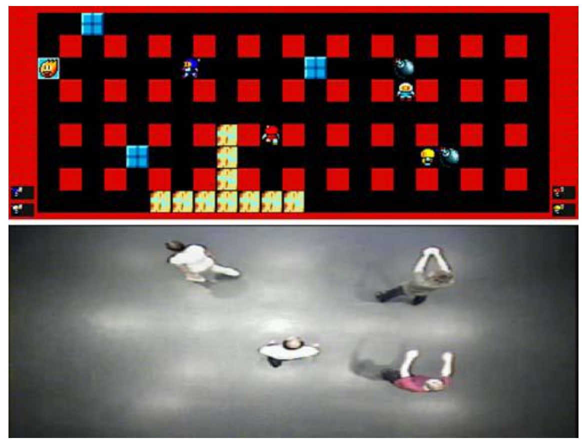

Figure 11: *Body-Driven Bomberman* [43]

In the *Age Invaders* exergame [39], co-located players move along a large electronic game floor and shoot virtual rockets using hand-held triggers (see Figure 10). Giving players the ability to target opponents or dodge incoming virtual rockets makes competition dependent. Similar dependent competition is found in the *Body-Driven Bomberman* exergame [43]. Computer vision captures the movements of co-located players, and is used to control each player's on-screen character. The goal of the game is to strategically plant virtual bombs in order to destroy the characters of opposing players (see Figure 11).

The exergames discussed above demonstrate various approaches for supporting dependent competition in exergames. These include shared targeting (e.g., Breakout for Two, Table Tennis for Three) and virtual combat (e.g., Remote Impact, Age Invader, Body-Driven Bomberman). User studies of Body-Driven Bomber indicate that players were motivated to play by the physical movement involved and the overall fun of the game [43]. This suggests a relationship between enjoyment and the dependent competition of the game. Similarly, experiments with Air Hockey over a Distance and Table Tennis for Three reveal that players enjoy dependent competition in exergames [58, 59]. Despite these results, the effect of dependent competition on motivation in exergames has not been studied directly. Further investigation would help to reveal effective design approaches for dependent competition in multiplayer exergames.

Competition and cooperation represent the two modes of interaction in multiplayer exergames. However, player actions can occur in different configurations of space. The following section explores the spatial configurations of multiplayer exergames.

4.2 Spatial Configurations

Existing exergames support co-located or distributed play. These spatial configurations are examined in the subsections 4.2.1 and 4.2.2 below.

4.2.1 Co-located Play

Co-located play occurs in the same location. Co-located multiplayer exergames require players to be in the same place. Existing exergames support co-located play using shared displays or ubiquitous environments.

Shared Displays

Display sharing is common in co-located multiplayer console games. For example, *Halo* splits the screen into four regions when in four-player mode. A similar split-screen approach is used in the Wii Sports tennis exergame. Academic co-located exergames use a shared display approach without dividing the screen. For instance, the set of Body-Driven games all use a single large display [43]. Co-located players interact in front of a projected display (see Figure 5). A shared single display is also used in the Nautilus [91] and Frozen Treasure Hunter [106] exergames.

Ubiquitous Environments

Co-located play in the socio-ec(h)o [98] exergame is supported by a ubiquitous environment. Specialized lighting, audio, and video projection surfaces act as interfaces for the game. Co-located players must listen to and observe the environment in order to gain clues. The clues help players coordinate their movement in order to advance to the next level. Similarly, the Age-Invaders [39] exergame requires a special play environment. Co-located play is made possible by having players move along an electronic game floor. The floor is comprised of a series of display tiles, and provides players with game information (see Figure 10). For example, when a player fires a virtual rocket using a hand-held trigger, the rocket’s path is displayed on the floor.

The examples above show that co-located play in existing exergames is made possible with shared displays or elements of a ubiquitous game environment. The tradeoffs of each approach have not been examined to date.

4.2.2 Distributed Play

Distributed exergames allow people in different geographical locations to play together. Distributed play is difficult without some shared awareness of each player. Various awareness approaches exist in distributed multiplayer exergames: audio, video, virtual avatars, and haptic feedback.

Audio

The *Jogging Over a Distance* exergame supports distributed play using augmented audio [61]. The system allows two people, in different locations, to run together. Each runner wears a headset allowing her to communicate with her partner. Depending on a runner's pace in relation to her partner's, the voice of her partner will appear from either in front or behind. The use of spatial audio allows communication between the players and provides awareness of presence and running pace.

Audio and Video

Several exergames allow for distributed play using two-way video and audio transmissions. For example, the Push'N'Pull exergame [60] includes a video conference feed in addition to the game window. Video conferencing allows the two players to communicate and observe each other's actions in order to more easily cooperate. Audio and video support is also found in the Breakout for Two [60], Airhockey over a Distance [58], and Table Tennis for Three [59] exergames; however, in these games, video is overlaid onto the actual game window. For example, in Breakout for Two, video of an opposing player is projected onto a large display with virtual targets appearing overtop of the image (see Figure 8). Video and audio allows players to see and hear each other as though they are separated by a pane of glass [60]. Audio and video provide awareness of a player's presence, identity, and actions.

Avatars

The Heart Burn exergame supports competitive play using virtual avatars [88], similar to the approach used in many popular online video games (e.g., *Halo, World of Warcraft*). Each player is represented in the game by an onscreen truck (see Figure 12). Awareness of a player's performance is revealed through the in-game actions of her avatar. In the Frozen Treasure Hunter game [106], two distributed players control a single shared avatar. One player controls the speed and direction of the avatar while the other player defends the avatar from incoming projectiles. In addition to the shared avatar, an audio feed between players is used to support cooperative play (see Figure 7). Generally, avatars reveal awareness of a player's presence and actions.

Figure 12: *Heart Burn* [88]
(bottom-right: player controls on-screen truck by pedaling on a recumbent bike)

Haptics

The Telephonic Arm Wrestling system [102] was built to allow people in different geographical locations to compete in an arm wrestling match. Although the system was created as an art installation, it demonstrates the potential for haptic feedback in supporting distributed play. The haptics in Telephonic Arm Wrestling provide awareness of player actions. Currently, there are no existing distributed exergames using haptic feedback between players.

Existing exergames demonstrate various approaches for making distributed play possible. These techniques aim to provide players with some level of awareness about each other's activities. The tradeoffs of each approach, and the effect of awareness on interaction in exergames, have not been explored to date.

4.3 Temporal Configurations

Play in multiplayer exergames occurs in two configurations of time. Section 4.3.1 examines synchronous play, and section 4.3.2 reviews asynchronous play.

4.3.1 Synchronous Play

Synchronous play occurs in the same period of time, and is the most common configuration in multiplayer exergames. For example, in the competitive Breakout for Two [60] exergame, a game takes place between distributed players at the same time. Similarly, Nautilus [91] is a cooperative and co-located exergame where players must be together at the same time in order to participate. Existing exergames demonstrate that synchronous play is possible in competitive and cooperative modes, and in co-located and distributed settings.

4.3.2 Asynchronous Play

Asynchronous play does not occur in real-time. For example, the *Triple-Beat* [68] system allows a jogger to compete against other people asynchronously. Using a mobile device, a player can see how her performance compares to the past performance of other users. The Triple-Beat display shows a player if her current performance is above or below that of another runner's earlier performance.

Triple-Beat is currently the only existing asynchronous exergame. Asynchronous games in cooperative modes or co-located settings have not been explored. Additionally, it is unclear what the tradeoffs of asynchronous play are, and its effect on motivation in multiplayer exergames.

4.4 Analysis

Play in multiplayer exergames occurs over several dimensions of time, space, and modes of interaction. The examples presented in this section explore the design space for supporting play along these dimensions. Further investigation into the tradeoffs of the various combinations of techniques would be valuable for designers of exergames.

Co-located and synchronous multiplayer exergames may suffer from similar travel and scheduling problems found in group exercise (as discussed in section 3.1). Distributed exergames have the potential to reduce the need for travel, and asynchronous exergames may solve issues of scheduling. Currently, it is unclear how various configurations of time and space affect exercise motivation and adherence.

Existing multiplayer exergames provide shared awareness among players using a variety of techniques (e.g., audio, video, avatars, and haptics). More research is required to determine what awareness mechanisms best support group cohesion and increase motivation in exergames.

Modes of interaction in exergames allow for different player experiences (e.g., competitive play vs. cooperative play). However, people with different capabilities may have difficulty playing together due differences in physical performance. This problem is further explored in the next section.

5. Supporting Differences in Skill and Ability

People with significantly different fitness levels can have a hard time exercising together as large differences in performance can lead to de-motivation [20]. For example, high school students who perceive themselves as inept sometimes fear they will let their team down and become discouraged to play group sports [36]. Additionally, competition may become stale if one opponent has a significant advantage over another. This is an important problem in multiplayer exergames since a person's exercise adherence is related to her physical capabilities [25]. This section reviews existing approaches for balancing play in multiplayer exergames: dynamic balancing, and asymmetric roles.

5.1 Dynamic Balancing

Similar to group sports, unbalanced play in multiplayer exergames can arise due to differences in fitness levels among players. Dynamic balancing automatically adjusts in-game parameters to better support competition among players.

The Age Invaders [39] exergame supports active play among family members using dynamic balancing. Age Invaders was designed to address potential differences in physical capabilities between young and old relatives. Game parameters (e.g., difficulty and response time) are automatically adjusted for each player depending on their age. During the game, each player follows a pattern displayed on an electronic game floor (see Figure 10). A player's path is adjusted based on her age, so that agile young players follow more difficult paths than their older opponents. The effectiveness of dynamic balancing in Age Invaders has not been experimentally tested. For instance, the proposed balancing technique is based solely on age and does not take into account differences in fitness levels among competitors of the same age.

The Heart Burn [88] exergame includes dynamic balancing to address differences in fitness levels. Heart Burn uses age in addition to heart rate as parameters for balancing. In the game, a player pedals a recumbent exercise bike to control the speed of her on-screen truck (see Figure 12). Two players race their trucks along a virtual track in an attempt to be the first player to cross the finish line. A second version of the game uses heart rate scaling to control the speed of a player's truck. The closer a player's heart rate is to her target heart rate, the faster her truck will move. Experimental results that Heart Burn's dynamic balancing – based on age and heart rate – can allow for improved competition between people of significantly different fitness levels [88].

5.2 Asymmetric Roles

Play among people with different abilities can be supported by providing a set of different in-game roles. For example, several roles exist in team sports like hockey and soccer (e.g., offense, defence, and goalie). Similarly, asymmetric roles can be seen in video games. For instance, *Mario Kart: Double Dash* has both driver and gunner roles.

The *Age Invaders* [39] and *Human Pacman* [17] multiplayer exergames include two roles: seated players, and active players. In both games, the active players are supported by remote players who provide in-game items or game-state information. This approach allows players with different physical capabilities to play together. For instance, players who are limited physically can interact with active players. There are potential limitations to this approach: differences in fitness levels among active players may still exist, and seated players fail to benefit from the intended physical activity of exergaming. The effectiveness of dynamic balancing in Age Invaders and Human Pacman has not been experimentally validated.

The *Frozen Treasure Hunter* exergame [106] supports two asymmetric roles. One player acts as a driver using a recumbent bicycle, while the other player acts as the defender using a Wii remote. This configuration allows people with different physical capabilities to play together. Additionally, physical activity is supported in both asymmetric roles.

The games presented in this section show the feasibility of implementing asymmetric roles in multiplayer exergames. However, there is currently a lack of experimental results to demonstrate the degree to which asymmetric roles support differences between players.

5.3 Analysis

Existing exergames support differences in ability using two approaches: dynamic balancing and asymmetric roles. The games discussed in this section demonstrate the feasibility of these techniques in multiplayer exergames.

Ladders and handicapping are common in sports and traditional games. Ladders rank opponents by skill level in an effort to allow for more balanced competition. Handicapping gives superior opponents some form of disadvantage, or gives an advantage to inferior opponents. To date, these approaches have not been explored in multiplayer exergames. Both approaches require some measure of past performance, making it challenging to apply them to new players. Additionally, ladders typically separate players and thus make it difficult for friends or family members to play together.

The effectiveness of dynamic balancing in the Heart Burn game has been experimentally validated [88]. The heart rate scaling technique in Heart Burn was found to be effective in instances of large differences in fitness levels. However, dynamic balancing should be subtle enough so that game play feels natural. Otherwise, opponents may feel a hollow sense of victory if they are aware of the balancing mechanism. Additionally, more refined techniques may be required to balance competition among players who are more evenly matched.

The effectiveness of asymmetric roles, to support differences among exergame players, has not been evaluated to date. Large difference in fitness levels could still impact play, and the performance of a team could be limited by the player with the lowest physical capabilities. Other approaches to support differences in ability have not been explored, such as combining asymmetric roles and dynamic balancing.

6. Quality and Effectiveness of Exercise

An underlying goal of multiplayer exergames is to promote physical activity in an effort to maintain and improve cardiorespiratory health (i.e., the function of the heart and lungs). Therefore, it is important to consider whether existing exergames provide beneficial exercise. There are numerous studies investigating the health benefits of single-player exergames and we infer that these results transfer to multiplayer exergames. Some anecdotal evidence exists regarding physical exertion in multiplayer exergames. For example, players of *Breakout for Two* [57] and the *Body-Driven Games* [43] report being sweaty, tired and sore, although no physiological measurements are provided. Currently, there are no experiments evaluating the exercise provided by multiplayer exergames.

This section examines the general effectiveness of physical activity in exergames. Section 6.1 reviews standards for recommended exercise. These standards are used to evaluate the physical demands of single-player exergames in section 6.2. Finally, section 6.3 examines exergames designed to improve accessibility to aerobic training.

6.1 Recommendations for Effective Exercise

In order to evaluate physical activity in exergames, it is important to review the criteria for effective cardiorespiratory exercise. The *American College of Sports Medicine* (ACSM) is the largest sports medicine organization in the world, and provides research and guidelines for physical activity. The recommendations of the ACSM [73] are considered the standard for effective exercise. The recommendations for physical activity include:

- *Frequency*: 3 to 5 days a week.

- *Intensity*: 65% to 90% of maximum heart rate, or 50% to 80% of maximum oxygen uptake reserve (i.e., the difference between the maximum and resting capacity of a person's body to utilize oxygen).
- *Duration*: 20 to 60 minutes of continuous or intermittent aerobic activity (duration dependent on the intensity of activity).
- *Mode*: any aerobic activity using large muscle groups and maintained continuously.

Comprehensive exercise regimes should also include training to improve and maintain muscular strength and endurance, and flexibility. To address this, the ACSM recommends two forms of training:

- *Resistance training*: one set of 8 to 10 exercises (8 to 12 reps) that target all muscle groups, two to three days a week.
- *Flexibility training*: stretching of the major muscle groups a minimum of two to three days a week.

The ACSM recommendations provide a measure for the effectiveness of exercise in exergames. Many existing exergames aim to improve and maintain cardiorespiratory health. Therefore, experimental analysis of exergames tends to focus on frequency, intensity, and duration of exercise. The following section reviews the effectiveness of physical activity in existing exergames based on the ACSM recommendations.

6.2 Physical Demands of Exergames

Several studies have explored the physiological effects of exergaming. The results of these studies reveal general features of physical activity in exergames: intensity and frequency of exercise, and flexibility and resistance training.

6.2.1 Intensity

Several exergames have been found to provide sufficient exercise intensity based on the recommendations of the ACSM. Exercise intensity is related to three factors of exergames: mode of physical activity, duration of exercise, and player population.

Mode of Physical Activity

The ACSM guideline for mode of exercise is "any activity that uses large muscle groups, which can be maintained continuously, and is rhythmical and aerobic in nature" [73].

In a study of children playing games for the *Sony EyeToy*, greater energy expenditure was observed in exergames requiring whole-body movement [47]. The EyeToy is a camera that uses computer vision techniques to capture a player's body movement, and is designed for use with the *PlayStation 2*. Of five EyeToy games investigated, only the *Knockout* and *Homerun* exergames provided effective intensity (i.e., intensity meeting or exceeding the ACSM recommendations). Knockout is a boxing simulation game where players must punch and dodge an on-screen opponent (see Figure 14). In Homerun, a player swings her arms in order to bat in-coming virtual baseballs. The physical activity in Knockout and Homerun involve major upper-body movement and some lower-body movement. Children playing both these games were found to reach at least 66% of their maximum heart rate [47]. Similarly, the *EyeToy:Groove* game requires significant body movement. Players move around to hit on-screen targets in rhythm to music. Adults achieve an average of 78% of their maximum heart rate when playing EyeToy:Grove [46].

Figure 13: ***Dance Dance Revolution***

Figure 14: ***EyeToy - Knockout***

Some exergames involving mostly lower-body movement have been shown to provide effective exercise intensity. In *Dance Dance Revolution* (DDR), input is captured using an electronic floor-mat. Players perform a series of dance moves in rhythm to music and on-screen cues (see Figure 13). Children playing DDR have been shown to average 65% of their maximum heart rate [95], and teenagers average 70% of their maximum heart rate [92]. These findings meet the minimum ACSM recommendations for exercise intensity. Although playing DDR requires substantial lower-body movement, it has been suggested that DDR may fail to meet exercise demands due to a lack of upper-body movement [95]. The *Jackie Chan's Run* exergame, for the *XaviX* console, uses a mat similar to DDR. Players step, jump, squat, and stomp on a floor-mat in order to control an on-screen avatar. Children average approximately 76% of their maximum heart rate when performing the lower-body motions in Jackie Chan's Run [55].

Figure 15: *Wii Sports* tennis

Figure 16: *XaviX* bowling

Alternatively, exergames involving limited body movement or simple gestures have been shown to provide insufficient exercise intensity. For example, *Wii Sports* tennis requires a player to swing only one arm (see Figure 15). Energy expenditure of children playing Wii Sports has been found to be insufficient to contribute to recommended activity levels [31]. The XaviX bowling exergame operates similarly to Wii Sports bowling (see Figure 16). Children playing XaviX bowling average approximately 49% of their maximum heart rate [55]. This level of intensity is below the ACSM recommendations. The *EyeToy:AntiGrav* game requires players to duck, lean, and reach to control an on-screen character. These actions involve mostly upper-body poses and also fail to meet recommended energy expenditure for exercise in teenagers [47].

Duration of Physical Activity

Intensity of physical activity in exergames is also related to the duration of play. The ACSM guidelines state that exercise should occur in "20-60 minutes of continuous or intermittent (minimum of 10-minute bouts accumulated throughout the day) aerobic activity" [73].

Although DDR requires substantial lower-body movement, insufficient exercise intensity may result from the limited duration of physical activity. For instance, Tan et al. [92] found that a single game of the arcade version of DDR only lasts an average of six minutes, and people rarely play more than one game. In contrast, the ACSM guidelines recommend a minimum of 20 minutes of continuous physical activity. The duration of activity in DDR may explain why several studies have found exercise intensity to be below the ACSM recommendations (e.g., [54, 84]). Additionally, when playing multiple games of DDR, the transition time between songs may result in a decrease in heart rate and oxygen consumption [95]. However, playing DDR continuously for longer periods of time could better contribute to recommended levels of exercise intensity [84, 95]. For example, Unnithan et al. [95] suggest that teenagers would have to play DDR for a minimum 65 minutes in order to reduce body fat.

Bowling exergames have been found to offer low exercise intensity [31, 55]. For example, energy expenditure in children playing XaviX bowling is considerably lower compared to playing XaviX Jackie Chan’s Run (1.89 kcal/min vs. 5.23 kcal/min) [55]. Lower exercise intensity in bowling exergames may be a result of longer periods of rest between physical actions. For instance, in Wii Sports bowling, a player swings her arm once to throw a ball and then waits for the pins to reset, similar to real-world bowling.

Population

The effectiveness of existing exergames is also dependent on player demographics. Research shows that exercise intensity during exergaming varies depending on: experience, age, body composition, and gender.

Differences in energy expenditure have been found between DDR players of different levels of experience. It has been suggested that inexperienced players may move more vigorously than necessary, resulting in greater exercise intensity than experience players [92]. However, people playing DDR at higher difficulty settings perform more dance steps (including greater arm movement) at a faster rate, have longer bouts of continuous play time, and transition faster between songs compared to less experienced players [84]. These observations explain why players with greater DDR experience meet recommended intensity levels for exercise while inexperienced players do not [84]. More investigation is required to determine what level of experience and difficulty settings in DDR provide the most effective exercise.

Age has been shown to affect intensity during exergaming. For instance, children playing Wii Sports boxing expend more energy than adults [44]. This may be a result of greater trunk movement in children playing Wii Sports compared to adults [44]. Alternatively, adults playing EyeToy:Groove average 78% of their maximum heart [46], as opposed to teenagers who achieve approximately 53% of their maximum heart rate [47]. However, studies involving EyeToy:Groove differ in the amount of time people spent playing. Further research would help to reveal the differences in exercise intensity between age groups.

In a study comparing overweight and non-overweight children playing DDR, no differences in heart rate and oxygen consumption were found [95]. However, overweight children did expend more energy when playing DDR compared to non-overweight players. This illustrates the potential effect of body composition on exercise intensity in exergames. However, the relationship between body composition and physical activity in exergames has not been generalized to date.

Gender has been found to influence exercise intensity in some exergames. For example, male teenagers playing Wii Sports expend more energy than females [31]. Although girls have been shown to be less physically activity in general than boys [94], more research is required into gender differences in exergames.

6.2.2 Frequency

The ACSM recommends exercise be preformed three to five days a week in order to improve and maintain cardiorespiratory health [73]. The majority of exergame research involves controlled laboratory experiments, and therefore long-term frequency has not been evaluated.

Warburton et al. [100] compared the health benefits of stationary bicycle training to training with the *GameBike* peripheral. The GameBike is a stationary bicycle that acts as an input controller for entertainment consoles (e.g., GameCube, PlayStation 2, or Xbox). Fourteen male college students participated in an exercise program, and were divided into two groups: traditional training, and interactive training using the GameBike. After six weeks, the researchers saw a significant difference in attendance (78% for the GameBike participants, and 29% for traditional training participants). The results of this study demonstrate that enjoyment of some exergames increases exercise motivation which leads to more frequent physical activity [100]. Despite these findings, it is currently unclear how to properly promote frequent exercise using exergames. Additionally, the study was confined to a laboratory setting and only lasted six weeks. Further investigation into long-term frequency of physical activity in exergames would be valuable.

6.2.3 Flexibility and Resistance

The ACSM recommends resistance and flexibility training in order to improve muscular strength and overall flexibility; however, few existing exergames target this form of physical activity. The

Push’N’Pull [60] multiplayer exergame uses an *Exer-Station* resistance training device to capture player input. A player must apply force to the Exer-Station in order to control on-screen objects. Although a player’s physical actions in Push’N’Pull could contribute to resistance training, this has not been experimentally validated. The *EA Sports Active* program allows players to use their Wii for customized fitness programs. Sports Active includes a training band that can be used for resistance training (e.g., arm curls).

Flexibility training can be found in some commercial exergames. For instance, the *Wii Fit* program supports customized fitness routines. Wii Fit includes Yoga and other activities intended to increase a person’s flexibility. Similarly, *EyeToy:Kinetic* also includes games and routines designed for flexibility training.

Existing exergames demonstrate how resistance and flexibility training can be incorporated into games. The strength and flexibility benefits provided by these exergames have not currently been evaluated.

6.3 Accessibility to Aerobic Training

Some exergames have been designed to make exercise more easily available to people with limited mobility. This section reviews existing exergames that improve accessibility to exercise, and the associated cardiorespiratory benefits.

The *GameCycle* training device acts as an input controller for the Nintendo GameCube console. Upper-body exercise replaces game pad controls. For example, in racing-style games, a player turns the hand-held cranks to move her on-screen vehicle forward, and tilts the cranks to steer (see Figure 17). A 16 week study of adolescents with spinal cord dysfunctions, using the GameCycle three times a week, resulted in substantial health benefits [103]. Six of eight participants reached at least 50% of their oxygen consumption reserve, and seven out of eight participants reached at least 50% their heart rate reserve. The ASCM recommends intensity in the range of 50% to 85% of oxygen uptake reserve or heart rate reserve [73]. Additionally, the majority of the participants increased their maximum work capabilities by the end of the study. These results show that the GameCycle can improve exercise capacity in adolescents with spina bifida, and provides an additional outlet for physical activity.

Figure 17: *GameCycle* system [103]

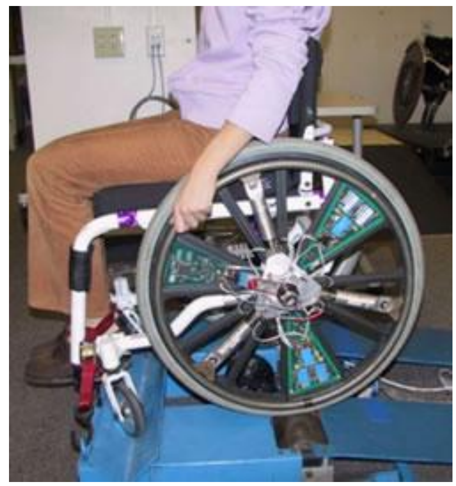

Figure 18: *GameWheels* system [67]

The *GameWheels* [67] system was developed to support exergaming for wheelchair users. A user's wheelchair rests on a series of rollers which measure rotation of both the left and right push-wheels of the wheelchair. These measurements are interpreted into X and Y coordinates for input control of computer games (see Figure 18). In a study comparing exercise with and without the GameWheels system, significant advantages of GameWheels were found [67]. Greater average ventilation range and oxygen consumption was found in players using GameWheels compared to traditional training. GameWheels also allowed players to reach and maintain their training zones faster. These results illustrate improved accessibility to exergames for wheelchair users and the related positive health benefits.

The GameCycle and GameWheels systems show that exergames can help promote substantial physical activity for people with limited mobility. Both systems are capable of providing similar or greater health-related benefits found in traditional exercise. Currently, there is a lack of exergames for limited mobility users designed to provide resistance and flexibility training.

6.4 Analysis

Existing research demonstrates that the effectiveness of exercise in exergames is dependent on several factors: mode of activity, duration of exercise, population, and frequency of exercise. Exergames that require whole-body movement for sustained periods of time appear to be more capable of supporting beneficial exercise, but this has not been experimentally validated. Research also demonstrates that the exercise provided by exergames may vary from person to person. For instance, differences in body composition and age can affect quality of exercise. Currently it is unclear how the frequency of playing exergames influences exercise effectiveness. However, frequency appears to be related to the degree of exercise motivation provided by exergames.

The majority of studies on the health-related benefits of exergames focus on commercial systems. Many commercial exergames have been designed to provide novel input and not necessarily intense physical activity (e.g., Wii and EyeToy). Exergame peripherals that support exercise comparable to real-world training (e.g., GameBike and GameWheels) appear to offer greater health benefits.

Most experiments on exergames involve a single game or peripheral. Therefore, there is a lack of comparison across existing exergames. Similarly, there are currently no general design guidelines for providing effective physical activity in exergames.

In cases where positive health benefits have been found in exergaming, intensity levels tend to meet only the minimum recommendations of the ACSM. Additionally, most results focus on average exercise intensity, and individual differences may vary. For example, children playing DDR average 65% of their maximum heart rate with a standard deviation of 7% [95]. The ACSM recommends exercise in the range of 65% to 90% of maximum heart rate. Therefore, many children playing DDR may not meet the minimum exercise recommendations for improved health.

Experiments to date have focused on the health-related benefits of single-player exergames. We presume that the results of multiplayer exergames will be similar to single-player games since the main difference is the addition of other players. For instance, single-player Wii Sports tennis likely supports the same intensity and duration of physical activity as multiplayer tennis. However, the positive motivational aspects of group activity may provide additional benefits in multiplayer exergames. Further investigation would help reveal the tradeoffs between single-player and multiplayer exergames.

7. Conclusion

The underlying hypothesis of exergames is to improve personal health by motivating physical activity. Multiplayer exergames attempt to include the motivational aspects of group activity by combining entertainment with group exercise. This paper provides an overview of the design fundamentals of multiplayer exergames.

Patterns of human behaviour and motivation offer a theoretical background for the development of multiplayer exergames. However, further research is required to determine how to best promote active behaviour through exergames.

Group-based physical activity has been shown to positively affect exercise motivation. Multiplayer exergames can target the motivating aspects of group exercise in order to better motivate physical activity. Additionally, multiplayer exergames may be able to combine some of the conveniences of home-based exercise with group activity.

Player-to-player interaction in multiplayer exergames occurs over several dimensions: time, space, and mode of interaction. Existing exergames demonstrate the feasibility of supporting play over these contexts. Additional research into the tradeoffs of each approach would be beneficial for designers of multiplayer exergames.

Players of multiplayer exergames may be limited by differences in skill and ability. For instance, players with different fitness levels can have a hard time playing together. Dynamic balancing and asymmetric roles are existing approaches for supporting more effective play in exergames. To date, research into balancing in multiplayer exergames is limited, and further investigation would be valuable.

Multiplayer exergames must support effective exercise in order to improve and maintain health. Research shows that multiple factors influence the quality of exercise provided by exergames. For instance, the mode of activity, duration and frequency of play and player demographics influence quality of exercise. Further research would allow for the development of guidelines for implementing effective exercise in multiplayer exergames.

The popularity of the Nintendo Wii, and recently announced motion capture systems for the Xbox 360 and PlayStation 3 indicate growing interest in exergames. Multiplayer exergames offer the potential to promote exercise motivation and adherence, and have only recently been explored. Examining the design fundamentals of multiplayer exergames will allow for more effective games in the future.

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