Spaceship Launch: Designing a Collaborative Exergame for Families

Herman Saksono[1], Ashwini Ranade[2], Geeta Kamarthi[2], Carmen Castaneda-Sceppa[2], Jessica A. Hoffman[2], Cathy Wirth[2], Andrea G. Parker[1,2]

[1]College of Computer and Information Science
Northeastern University
360 Huntington Ave. Boston, MA 02120

[2]Bouvé College of Health Sciences
Northeastern University
360 Huntington Ave. Boston, MA 02120

{saksono.h, ranade.as, kamarthi.g}@husky.neu.edu, {c.sceppa, j.hoffman, c.wirth, a.parker}@neu.edu

ABSTRACT

Parents play a critical role in facilitating children's physical activity, as they are an important source of modeling and support. While Human-Computer Interaction (HCI) researchers have explored exergame design for children or adults separately, an important open area of work is identifying design guidelines for family exergames. One question that researchers have increasingly posed is, how can exergames be designed to avoid potential negative consequences of competition? To address these questions we designed Spaceship Launch, an exergame for parents and kids in lower income neighborhoods, where obesity is most prevalent. We describe our iterative design process: the formative study to identify design opportunities, our resulting system, and our field evaluation of the tool. Our findings highlight the impact of SL on physical activity intentions, and how parental preferences for in-game competition were aligned with the psychological needs of relatedness and competence. We conclude with design recommendations for future family-focused exergames.

Author Keywords

Exergames; serious games for health; physical activity; collaborative games; gamification; competition.

ACM Classification Keywords

H.5.3 [Group and Organization Interfaces]: Computer-supported cooperative work

General Terms

Human Factors; Design.

INTRODUCTION

Combating childhood obesity begins with the family. In this environment, preventive health behaviors such as physical activity (PA) can be modeled and supported [13]. Human-computer interaction (HCI) researchers have explored the use of interactive computing systems for promoting PA and reducing sedentary behavior, in the form of exercise games (*exergames*) [18,41], gamified PA visualizations [5,17], and social support systems [23,38]. However, very little work has explored how systems should account for familial influence, even though parental modeling is a strong predictor of children's PA behavior [8]. There is rich opportunity for HCI innovation in this space, given the barriers to modeling that families often face (*e.g.,* limited opportunities to exercise together).

The overarching question in our work is: how can parent-child interaction in a technology-based intervention facilitate PA promotion and what are design guidelines for creating such tools? To answer this question, we conducted an 8-month iterative design process. Our work began with a formative study examining parental attitudes towards, and perceptions of PA, as well as current PA behaviors. One key finding of this study is that while the parents provided support for their child to be physically active, they provided little PA modeling for their child, which research has shown to be important for increasing children's PA levels [21,24].

Using this finding as a starting point, we explored how an exergame could encourage PA modeling. Prior work has raised concerns about the negative impact that competition can have on user engagement in exergames [17,18,41]. As such, we attempted to avoid the potential negative effects of competition by designing a *collaborative* game environment. We developed Spaceship Launch (SL), a collaborative exergame for parents and young children, aged 3-8. Prior work in HCI has not extensively studied exergames in the context of the family unit. Informed by social cognitive theory (SCT) [2], SL was designed to encourage the parent and child to work together to be more physically active at a moderate or vigorous level. We conducted a three-week field study of SL with 13 families in a predominantly lower-income neighborhood in the northeast United States. This demographic was chosen due to the increased barriers to PA facing low-income families. To study use of and engagement with SL, we conducted interviews and participatory design workshops.

Through our inductive analysis, we found that while SL was a collaborative game, families had strong, yet nuanced desires for increased competitive game elements. Using self-determination theory (SDT) [28] as an analytic lens, we further unpacked this value. Our findings suggest that parents' desire for competition was partially driven by the psychological needs and SDT constructs of relatedness and

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competence. Our results highlight the value of fulfilling this need as a means of nurturing exergame engagement.

We contribute to HCI research by providing a case study exploring how technology can promote increased PA in families. We report on our formative study, the design of SL, and our evaluation of this tool. As there has been limited work in this area, our findings can help motivate future research in this space. We further contribute to HCI by proposing four design implications for future work, specifically articulating the value of promoting family PA through a task-mastery exergame environment. Finally, prior work has not explored how the feeling of relatedness between family members affects exergame engagement and PA promotion. Our findings highlight theory and empirically based directions for future work.

RELATED WORK

Our work is motivated by public health research showing the importance of family-based PA interventions. We begin with an overview of this literature and then briefly overview self-determination theory, which helps characterize PA motivation. We conclude with a discussion of HCI research that has used games and *gamification* (game design elements used in non-game contexts [7]) to promote PA, focusing on competition in such systems.

Family-based Physical Activity Promotion

The family environment can have a profound influence on health behaviors through parental provision of modeling, support, and influence [30,35]. A ten-year study found that parental involvement in childhood obesity prevention efforts yields a higher rate of success [9]. Parental PA modeling has been cited as a predictor of children's PA [8,21] and there is a significant correlation between the time parents spend being active and children's PA [24]. However, the impact of parental modeling may be diminished if the child does not directly see how active their parent is [39]. Yet, PA modeling is challenging because families often face barriers to exercising together (*e.g.,* time constraints and differing physical capabilities*)* [36]. These barriers suggest opportunities for systems that facilitate PA modeling.

Prior HCI research has explored the design of *exergames* (*i.e.,* games in which play is driven by an individual's PA) [32] and activity sharing tools [4,15] for family health promotion. These systems often incorporate a social element, whereby intra- and inter-family performance is compared. While such comparisons can encourage higher system participation [4],.Grimes *et al.* [12] noted parental concerns regarding the impact of competitive design elements on children, for example, questioning how comparisons might impact the child's self-esteem. While this prior work suggests the potential of using technology to promote healthy behaviors in a family context, work in this area is just beginning to emerge, and little is known about how such systems can effectively engage family members.

Self-Determination Theory

Self-Determination Theory (SDT) explains how individuals are motivated to engage in various activities [28]. Within SDT, motivation is fostered by the satisfaction of psychological needs, including competence and relatedness. *Competence* is an individual's perceived capacity to complete a task. *Relatedness* is defined as the need to feel *connected* to others, to be *concerned* for them, and to feel *accepted* in a social environment. Prior work has shown the value of SDT in predicting PA engagement [22] as well as computer game engagement [29], suggesting its promise as a theoretical basis for exergame design and evaluation. Moreno *et al.* [22] examined two types of motivational environments: task-mastery climates (*i.e.,* the focus is on the task domain and personal improvement) and ego-involved motivational climates (*i.e.,* the focus is on comparisons with others). Their findings showed that a task-mastery climate positively predicted the fulfillment of the psychological needs posited by SDT, which in effect predicted enjoyment. On the other hand, an ego-involved climate predicted none. Motivational climates that emphasized cooperation and effort fulfilled the need of competence as it is "a self referenced criteria, which is far more controllable" [22]. A cooperative climate that avoids peer comparison also nurtured the feeling relatedness.

Competition in Exergames & Gamified PA Visualizations

Increasingly, HCI researchers have examined how games can encourage increased PA. As the goal of such serious games is not only to provide entertainment but also encourage a positive shift in behavior [27], it is critical that designers carefully examine ways of avoiding undesirable outcomes [26]. The potential negative effect of competition has been highlighted in child-focused exergame research. iFitQuest, designed for adolescents, is a set of two mini exergames with open-ended goals that players can freely choose [18]. The game mechanics are driven by players' runs in the real world. Similarly, the American Horsepower Challenge (AHPC) encourages school children to walk by comparing the aggregated step count of their school versus other schools. The school with the most steps wins [41]. Evaluations of iFitQuest and AHPC revealed that challenges emerged due to comparisons and competition. One iFitQuest player exercised in a separate area to be out of sight from peers and one player ridiculed others with lower scores [18]. One AHPC player was uncomfortable sharing his contributions to the game with peers, because he was concerned with not being sufficiently competent [41]. Research on gamified PA visualizations has also raised concerns about competition, with a participant in one study noting "*there is enough competition in real life*" [17].

To avoid undesired effects of competition in the context of family health monitoring tools, Grimes *et al.* [12] recommended that such tools be designed to facilitate collaboration between family members instead of competition. These systems can be designed by emphasizing, "how healthfully the family is living as a unit,

rather than how each person is doing compared to other". This recommendation of avoiding an others-referenced climate resonates with prior research on PA [22,40], which argues that task-mastery climates are more effective for maintaining enjoyment. In summary, competition is clearly a design element that must be carefully considered and designed. Our study revealed important considerations around competition for family-based exergames.

IDENTIFYING DESIGN GUIDELINES

To begin exploring how technology might facilitate PA in families, we conducted a formative study with 13 parents. The study was conducted at a community gym that hosts a free program for families with young children (approximately aged 3-8) to be active together. The program is held in a predominantly lower income neighborhood in Boston, MA, United States, in an attempt to help families overcome barriers to exercise in this context (*e.g.,* limited access to safe play spaces [1]).

Formative Study Method

We used focus groups (n=13) to probe parental attitudes towards, and support for, their child's PA. There were two to six participants in each session. At this stage, we focused on parents (as opposed to their young children) as we felt they could more clearly express to us how much PA their family was getting, barriers to exercise, and the family's PA needs. Focus groups were audio-recorded and two researchers completed an iterative, inductive analysis of the transcripts, inspired by grounded theory analysis [33]. We independently coded the transcripts and met regularly to discuss and reconcile our codes. We then iteratively clustered codes into higher-level themes and identified relationships between themes through axial coding. Participants were first asked to complete a demographic survey at the start of the focus group. We administered a follow-up survey (n=10) using validated instruments to gain more insight about parental support for PA [20].

Formative Study Results

The focus group data suggests that parents provided support for their child to be active. This finding is somewhat unsurprising given that parents were recruited from a family-based PA program. Parents were informed about the importance of child PA and were actively seeking and providing PA opportunities. For example, P5 discussed how she seeks PA opportunities in an unconventional way:

> P5: When I'm driving around and I see someone playing soccer or something, I pull over and I ask more questions. I find out a little more… I feel like there's information out there.

Parents also discussed in detail the interplay of barriers that limit their ability to help their kids to be physically active. They also detailed their efforts to overcome the barriers and the disappointment of not being able to do so. The most apparent barriers were financial and informational; parents experienced difficulties finding PA programs (such as summer camps and soccer clubs) that were within their budget. P7 expressed her sense of helplessness:

Type of parental PA support or modeling (scale 1-5; 1: never, 5: daily)	**Avg**	**Stdev**	**Min**	**Max**
Encouraged PA	4.8	0.42	4	5
Provided transportation to PA	4.5	0.85	3	5
Watched kids' PA	4.1	0.87	3	5
Discuss the value of PA w/ kids	4.9	0.32	4	5
Engage in PA with kids	3.7	1.10	2	5

Table 1. Parental PA Support & Modeling in Formative Study

> P7: And I just feel like it's a catch 22, because you want quality childcare, and you know there's cost associated with that, but sometimes it feels like things are out of reach.

In some situations, financial and informational barriers were coupled with transportation and time barriers (having insufficient time to take their kids to PA opportunities). P5 summarized this interplay of barriers, implying her hopelessness in supporting her child to be active.

> P5: Some of the resources that are out there are either very far out and the drive is ridiculous just to get there, and I'm not driving to a situation where I come back to [local neighborhood] to go to work, or they're very, very expensive.

While parents made great efforts to support their child's PA, they rarely discuss exercising with their kids. This finding is further supported by the survey data: parents reported providing high levels of PA social support for their kids (*e.g.,* encouraging and watching kids do PA), but they less frequently engaged in "PA with kids" (Table 1). In addition, we used self-report height and weight data to calculate parental body mass index (BMI), and most parents were overweight or obese (n=11). A previous evaluation of the community gym showed that most parents rarely modeled moderate and vigorous physical activity during gym sessions [3]. Our results further elaborate on this prior work by shedding light on parental PA levels outside of the gym as well as their BMI data. Together these results characterize parents' limited PA levels and likely caloric imbalance.

These findings collectively suggest that parents are not engaged in recommended levels of PA (such as those articulated by the Centers for Disease Control and Prevention (CDC)), therefore minimizing the opportunity for modeling positive behaviors for their children. Going back to Thompson *et al.*'s [36] recommendation to design interventions accommodating the complex needs and demands of today's families (*e.g.,* the inability to exercise together), a potential design direction would be to develop a tool that helps parents and children to collectively pursue increased PA even if they do not exercise at the same physical location or at the same time.

SPACESHIP LAUNCH DESIGN AND EVALUATION

Based on our formative study findings that some parents do not or unable to model PA behavior for their children and that parents may not be engaging in recommended PA levels more generally, we designed Spaceship Launch (SL),

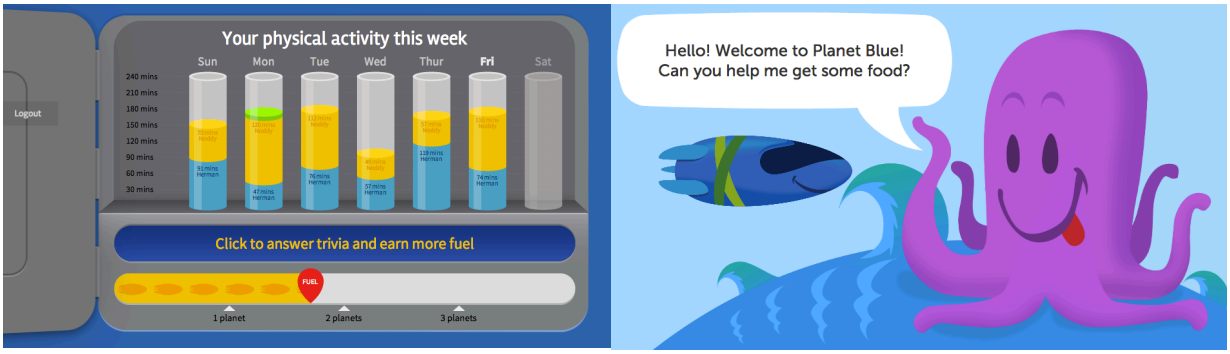

Figure 1. SL Dashboard (left) and Launch Game (right)

a collaborative exergame for promoting PA in a family context. SL consists of two elements: the Dashboard and the Launch game. The goal of the Dashboard is to facilitate collaborative PA reflection between the parent and child, whereas the Launch game provides virtual rewards as the parent and child team achieve recommended PA levels.

Design Rationale

SL is a collaborative exergame, where the team of a parent and a child must work together to meet the game's objective: achieving the CDC's recommended PA levels[1] (150 minutes of moderate or 75 minutes of vigorous activity for adults each week; 60 minutes of moderate to vigorous activity for kids each day). Using Fitbit activity trackers worn by the parent and the child, the game tracks the weekly minutes that each player spends in moderate and vigorous PA (MVPA). Fitbit accuracy has been validated by prior studies, (*e.g.,* [34]). The more time the team spends in MVPA, the more fuel the child receives to launch their spaceship to planets in the game.

Drawing inspiration from Grimes *et al.,* [12] about the potential of cooperative social interactions over competition in the family context, we designed SL as a collaborative game. Zagal *et al.* [43] described the distinction between competitive, cooperative, and collaborative game. In a *competitive game*, the objective is to outdo the other player. The mechanics ensure that one player wins and the other loses. In a *cooperative game*, the mechanics require two players to work together to achieve a collective goal, even if the individual goals may be different. In contrast, a *collaborative game* has intrinsic mechanics that guarantees players who work together to complete a collective goal will always get an equal benefit. If one player loses, then the other player will lose. El-Nasr *et al.* [31] found that collective goals encourage players to help each other, work out problems together, and laugh together.

The objective of SL is to collect as many minutes as possible per week to meet CDC recommendation. The rewards in this game are the ability to launch the virtual spaceship to a planet in outer space and the experience of fantasy and discovery of the planet inhabitants and environments. The planets and overall game visuals are designed for kids aged 3-8, because they are expected to be a driving factor of parental engagement with SL.

The SL Dashboard is designed for the parent and child to monitor their PA levels during the week and their fuel progress. The rationale behind this design is that some families may not be able to be physically active together, though the parent may be physically active at work and the child may be active at school. Observational learning is a central element of social-cognitive theory (SCT) [2]; this construct suggests that increasing opportunities for kids to observe their parents engaged in PA may lead to increased PA for the kids themselves. Furthermore, the PA visualization is designed for self-monitoring, which affords self-regulation, another important element of SCT. Finally, in our formative study parents repeatedly discussed experiencing elevated positive emotions when observing their child being active. Therefore, the Dashboard may provide an additional incentive for the parent to engage.

The second element of SL, the Launch game, articulated the game's task (meet recommended MVPA levels to gain spaceship fuel). In the Launch game, players could: see how many planets they can launch to, select the planet to visit, observe the launching experience, land on the planet, and complete a mission. Both the Launch game and the Dashboard are accessible through home devices as well as a large interactive display deployed during the gym sessions.

SL was implemented as a web application. The frontend was developed using HTML and SVG, which is controlled using the JQuery and SVG.JS JavaScript libraries. The backend was developed using Laravel PHP Framework; it stores and retrieves users' minute-by-minute time series PA data from Fitbit's server.

Evaluation Method

We evaluated the use and impact of SL in a 3-week field study with 13 families. Participants were recruited from the same community gym as in the formative study. 29 people participated, including 15 caregivers and 14 children.

[1] cdc.gov/physicalactivity/everyone/guidelines/adults.html

Northeastern University's Human Subject Research Protection approved the IRB protocol for this work.

At the beginning of the study, we showed participants how to wear the Fitbits and how to use the SL game and Dashboard. Participants then completed demographic and surveys to assess baseline PA intention [6] and parental PA modeling and support [20]. Participants were then given access to SL for three weeks; their SL interactions were logged by the system. We asked participants to log into the game at least once every week and recommended they check the Dashboard as often as possible. If more than three days had passed since their last login, participants were sent an email or SMS reminder to use the system.

After they had used SL for three weeks, we conducted semi-structured interviews with eight parents to understand their experience with the game and to what extent it affected their intention to be physically active and their PA modeling behavior. Our findings from this initial examination will inform the design of future iterations of SL, which will be more closely evaluated from the child's perspective. At the conclusion of the study, parents repeated the PA intention survey that was administered at baseline.

In addition, we conducted participatory design workshops with four families: both caregivers (n=5) and their children (n=4) participated in the workshops, for a total of 9 participants. Participants were asked to redesign the SL Dashboard using a variety of art supplies (*e.g.,* colored papers, stickers, felt pens) so that the game better fit their needs. Each workshop included one to two families. Following the work of Yoo *et al.* [42], we encouraged iterative revision using prompting cards to elicit nuanced requirements and stories that are harder to attain in conventional interviews.

To help parents and children to iterate on the SL dashboard design, we gave each participant an instruction card that provided focused direction about what to design:

> "Redesign the SL dashboard so that you and your child could sit together and monitor your weekly physical activities."

After this first task was completed, we presented them with an envisioning card to help them revise their initial design:

> "Improve the way your dashboard works so that it fits better with your routine, your household, and your family's needs"

After families completed their revisions, we conducted interviews with them. We used their designs to probe deeper and better understand how the experience of using the game through the SL Dashboard affected their behavior and how it could be improved to encourage family fitness.

We conducted an inductive analysis of the interview and design workshop transcripts. Our approach was inspired by grounded theory [33]: we inductively open-coded the transcripts, iteratively clustering codes to arrive at a set of emergent themes. We then conducted axial coding to examine the relationship between the themes.

Type of parental PA support or modeling (scale 1-5; 1: never, 5: daily)	**Avg.**	**Stdev.**	**Min**	**Max**
Encouraged PA	3.40	1.06	1	5
Provided transportation to PA	3.33	1.18	1	5
Watched kids' PA	3.07	1.03	1	5
Discuss the value of PA w/kids	4.00	1.07	1	5
Engage in PA with kids	2.80	1.15	1	5

Table 2. Baseline PA Support & Modeling during Evaluation

Participant Overview

The majority of the participating caregivers were female (n=11) as well as the majority the children (n=10). This gender distribution reflects the general make up of gym attendees in which female caregivers are the majority (female=56.4%, male=35.9%, not reported=7.7%). Four caregivers also participated in the earlier formative study. Caregivers were mainly parents (n=13), but also included one grandparent, and an uncle. The median age of the caregivers was 39 and the median age of the children was 8. The BMI calculation indicated that most caregivers were obese (n=8) or overweight (n=3), with two in the healthy range (2 participants provided no data). The median household income was $20,000-$29,999 and the majority of the families lived in neighborhoods where the average household income is below the city's average (n=13).

Caregivers' intention to be physically activity appears to be low. Our baseline survey data indicated that the median number of times that caregivers intended to be physically active is a total of 5-8 times in the next 4 weeks. Similar to the findings in our formative study, our survey results suggest that caregiver support for child PA is moderate and the PA modeling is lower (Table 2). On average, caregivers self-reported that they sometimes exercised with their kids.

SPACESHIP LAUNCH EVALUATION RESULTS

Three themes emerged from our analysis. First, we found that the game seemed to help *increase PA intention*. Participant accounts helped us identify how they used SL as a motivational tool for exercise and to assess their PA. We also found that while SL was designed to be collaborative, most participants expressed nuanced preferences for competition. Finally, our results suggest that competition was desired because it was perceived as a catalyst for social interactions fulfilling the psychological need of relatedness.

Increased PA Intention

Having daily PA duration visualized through the SL dashboard and a target of game-defined PA duration seemed to affect most participants' *intention to be active*. Our PA intention survey showed that all but one participant intended to be at least as active as at the start of the study, if not more. Four participants reported an increase in intention; of the 6 that reported no change, 3 were already intending to be active at the maximum level (7 days/week) at the start of the study. These preliminary findings suggest

the potential value of SL for helping encourage sustained and increased desire to be physically active.

Our interview data mirrors these findings, shedding more light on the impact that SL had on participants' pursuit of PA. All but one of our interviewees said that the game increased their intention to be physically active. Some (P3, P8) intended to exercise individually, whereas others (P9, P1) intended to exercise with their child. The participants also expressed varying levels of intention. For example, the game's PA target led P3 to *contemplate exercising* as her awareness of the need to be more active increased.

> P3: I'm thinking to exercise more. Because my fuels were low. And I know I could do, I know I could do better than that.

Other caregivers were more motivated to change by *preparing to exercise*. P8 and P9 expressed the intention to change through by *reminding themselves* to exercise. P9 also spoke with her child about exercising to accomplish the game's target.

> P8: [Using the game made me say to myself,] "*Oh, I got to get up. Got to get out of the house. Got to do something*."

> P9: You know, you get your mindset. "*Okay, tomorrow I'm going to fill this tank up*" […] My daughter and I, we said "*Okay, we're gonna work*."

P1 went further in *preparing to exercise* by *identifying exercise opportunities* to earn game points. P1 also saw the need to earn game points *with* her child, and was expressed by her intention to *identify team exercise opportunities* that she and her child could participate in.

These varying intentions can be mapped to the Transtheoretical Model's stages of health behavior change [25]. Individuals who *contemplate exercising* may need further incentive to translate intentions into action, as traditional action-based programs may not be effective for them [25]. Participants who were *preparing to exercise* were making strides towards health behavior change, and the game provided them with a reason to exercise. However, unlike P1 who started to *identify exercise opportunities*, P8 and P9 did not explicitly do so. They may need ideas to proceed to action. While this could be supported through a database of PA ideas, it may be more sustainable if this is provided by other game participants. Stories from peers are potentially inspirational because they have been tried out by similar others [11].

Some participants translated these intentions into *actions to accomplish the game's objective* (*i.e.,* obtaining spaceship fuel by being physically active in a duration that meets the CDC's recommendation). Participants realized that the Fitbit tracks all kind of physical movement; therefore they come up with a diverse range of exercise opportunities. For example, P2 identified the relationship between the magnitude of her movement and the game points (spaceship fuel) that she will acquire. In the account below, after she *identified the exergame mechanics* she expressed her excitement when she shoveled the snow because she will get more spaceship fuel:

> P2: Oh, this is a good opportunity for me to get some, you know, points for my [spaceship]. So it helped to encourage me to want to go do Zumba and then with all the snow was there I was like, "*Oh, I'm shoveling!*"

Similarly, P15 expressed how the game encouraged him to *substitute the sedentariness* of sitting on a bus for a short ride, opting to walk instead. P1 also described how she substituted the sedentariness of taking the elevator: she deliberately took the stairs to get to the 7th floor to get water to earn more spaceship fuel. P1 also *planned exercise opportunities* that would help her succeed in the game, and she materialized the plan by exercising with her child:

> P1: So I got this tape, Shaun T. And it's a hip-hop moving tape. And I decided in the morning that's what we're going to do. So I did it, and it worked one day.

As SL recognized small PA efforts, game players started to *substitute sedentariness* with more physically involving activities such as walking or taking the stairs. This suggests that SL potentially increased the awareness of opportunistic exercise and helped reduce sitting. For participants who are aware of opportunistic exercise, the game provided reasons for them to do so, as suggested by the accounts from P1 and P2. For others, SL may provide an increased awareness of PA opportunities.

Nuanced Preferences Regarding Competition

As a collaborative game, SL was designed *not* to support competition. In a competitive game the mechanics guarantee that there is always a winner and a loser. In contrast, collaborative games have intrinsic mechanics that ensure two players who work together will either both win or both lose [43]. However, the interview data suggests that many participants desired competition. Five out of the eight participants we interviewed proposed competitive game elements even if we did not specifically ask them if they wanted competition. P1, for example noted that competition would make SL more fun and P3 noted that:

> P3: Sometime when you see that someone else is doing better, you want to do better.

It becomes evident that the notion of competition is multifaceted. While previous research has highlighted negative effects of competition [17,18,41] some form of competition may improve users' engagement with exergames. Our analysis highlighted the importance of understanding competition based upon the setting in which it takes place—*intra-family* and *inter-family*—and the relationships of the actors involved.

Intra-family Competition

While SL's game mechanics did not directly facilitate competition, such interactions between the parent and the child may have motivational value. P4, who initially stated that she was not motivated by the game, felt that competing with her child would be motivational for her. Parents

further discussed how competition is desirable because it facilitates various forms of interaction with their kids. For example, two parents envisioned how competition would lead to collective assessment of their PA as well discussions of the experience of playing SL with their children. P9 suggested that reviewing and making comparison between her and her child's PA levels is an enjoyable experience:

> P9: It's fun [to have a competition] to see how much you've done [during] the day. Like… my daughter and I might say, "*Okay, which one of us were [higher]?*"

P15 was also comfortable comparing PA levels with his child. He emphasized that it is not a "real competition" but rather an opportunity to observe his child's PA and discuss their game experiences.

> P15: It doesn't bother me [to have a competition with my child]… We don't really have to make it like a competition, you know, she just be happy to get to the [gym session], to really see how much [spaceship] fuel she got. At the end of the [gym session], we just could sit back and discuss how much fuel she earned.

Parent-child competition can also be an opportunity to bond. P6 felt that PA comparisons between the parent and the child are an opportunity to influence behavior by giving motivation and building confidence.

> P6: If your child is, needs more exercise and the adult doesn't need as much, you're kind of helping, using this as a way to kind of bond with your kid. And build some confidence and encourage her to get in shape.

Parents did not express any uneasiness when they saw they were less active than their child. P1 actually suggested the game explicitly show that her son beat her:

> P1: [Make the game say:] "You're beating your mom today!" Or yeah, "You did this many steps, and you outdid your mom!" […]
> *I: How would that affect you?*
> P1: It'll make me want to go beat him. [laughter]

P6 raised concerns about comparisons with younger children. He was concerned that if they do not perform well in the competition, they may feel incompetent and subsequently lose motivation to play the game:

> P6: There's people gonna feel bad [if they lose]. Especially little kids. Six, seven years old, they may say, "*Well, I'm not doing well. I don't want to do it anymore*."

In summary, parents discussed competition as being more than trying to win or be better than others. Their accounts suggest that parent-child competition in an exergame context may be valued as a means of catalyzing health-promoting social interaction, whereby the parent is able to help the child toward positive behaviors. These interactions may be in the form of observing, discussing, and encouraging PA. Our participants did not express any uneasiness when their PA was compared using the game. While our analysis focuses on the parental perspective, future work should examine children's reaction to their PA being compared with that of their parents.

While only discussed by one participant, an important area for further inquiry is the differing characteristics of individual families and how competition may have a motivational or de-motivational effect on different families. P6's remarks suggest that such competition may need to be cautiously designed to avoid negative consequences.

> P6: [The effect of competition] depends [on] if the family is very close. Sometimes having a competition can be fun. If the family is not really competitive type of family it can sometimes draw some people away. Because they'll feel like, "Oh, well. I don't want to bother doing this, because I'm not gonna win anyway."

P6 notes how the closeness of a family and their inherent competitiveness can impact how a competitive game is received. P6 went onto suggest that families be allowed to tailor competition to fit their unique characteristics.

> P6: I think within the game there should be a choice. You know, do you want to have a competition between members of your family. Or you guys want to monitor and just kind of keep track of each one. Without really put it in a competitive type of stance.

P6's quote suggests that the family environment and the relationship between family members may affect the outcome of competition in a family exergame.

Interfamily competition

Our participants also discussed the potential value of interfamily competition, distinguishing the place for competition between *familiar families* as compared to *new acquaintance families*. Two participants (P1 and P3) who are sisters imagined the value of family-to-family interactions that could emerge from competition:

> P1: We can compete against families. I think that would make it more fun… As long [as we]—*I guess*—sign a paper saying, "*No hard feelings."*

> P3: [In agreement with P1] we can play with different families or a household. […] I have three girls and one boy. [P1] has her son and her boyfriend… We can be competing against each other and come over to the house on Saturday or take turns and see who won or something.

P1 was slightly more cautious by warning that families should have no hard feeling when they lose. This highlights that while parents may be comfortable with a competitive environment, they acknowledged the potential negative effects that such game elements can yield.

These parents also supported competition between *new-acquaintance families*. However, P2 emphasized the need to share characteristics with the other family. These characteristics may include parental structure (*i.e.,* single or dual-parent*)*, number of children, or PA lifestyle.

> P2: I mean it'd be nice [to compete against], in my case, a single parent and two kids or somehow we would get paired

> kind of like [by] family types. Because, I mean, obviously if it's somebody who exercises all the time, we never do.

Similar to P1 and P3, P2 envisioned the interactions that may emerge in family-to-family competition. She suggested that competing with another family would allow her to discuss PA levels and ideas. She also felt that by communicating with the other family, they would be able to meet and exercise together. Her desire to use the game to exchange PA ideas suggests an opportunity to overcome the informational barrier that participants discussed in our formative study. In her account, P2 suggested that by being able to see other families' activity level, she could ask:

> P2: "*What did you do on day two when I see you were very active?*" It might give you some ideas that you didn't think of, things you could do. […] You may end up doing it together.

P2's comments seem to contradict the notion of competition as the pursuit of outdoing others. It may be that she saw competition as simply a benchmark to assess competence or that SL's task-mastery climate encouraged her to focus less on peer-referenced comparison.

In conclusion, similar to parent-and-child competition, caregivers also envisioned how social interaction may emerge in competitions with a familiar family or new-acquaintance family. They described how such interactions can elevate the experience, for example, by increasing the game's entertainment level or facilitating opportunities to meet and discuss their game and PA experiences. These social interactions could potentially help families break the informational barrier to support their child to be active.

Competition: Seeking Social Interaction & Competency

As we analytically studied the emerging themes, it become clear that caregivers' preferences regarding competition aligned with the two constructs from Self-Determination Theory (SDT): relatedness and competence. As discussed previously, this theory helps explain individuals' motivation to be physically active. In SDT, *relatedness* is described as the need to feel connected to others and be concerned about them [28]. Relatedness is also manifested as a need to feel accepted in the social environment [28]. As such, caregivers' desire for competition between others with a shared tie (the parent and child, familiar families, or new acquaintance families who share similar characteristics), and their interest in using competition as a springboard for social interaction may be reflective of their desire for relatedness. Indeed, prior work has shown that PA enjoyment is bolstered when people feel a sense of relatedness with those they are being active with [22].

In parent-child competition and familiar-family competition, the feeling of relatedness may already be present. Therefore game-supported relatedness in this context may be desirable to nurture existing feelings of connectedness. On the other hand, P2's desire to share similar characteristics with new-acquaintance families suggests the need to feel accepted, which is associated with the construct of relatedness. Exergames for such families may need to help nurture relatedness and highlight ways that families share similar characteristics.

Caregivers' positive attitudes towards competition may be further explained as a pursuit of the psychological need of *competence*, as defined by SDT. Competence is described as the feeling of control over the outcome of a task. The primary objective of SL is helping players develop PA competency, that is, the ability to be more physically active. Our findings suggest that the pursuit of competence was an important driver of parents' acceptance of competition. For example, one parent said that parent-child comparison is acceptable if the end goal is to achieve PA competency.

> P9: We compete with each other to see which one of us has moved more. So some days she moves a lot more than me. And some days we move equal. Some days I move more. But all positive, no negative. […] I think competition's good. With each other. As long as they're competing for positive things.

Caregivers and kids also *collectively assessed their PA* using the SL Dashboard. P9 described this in the previous quote where she made PA comparisons with her child day by day. P1 also described a similar comparison, and sometimes used this data to motivate their child by using the Dashboard to provide positive feedback:

> P1: After you see [the game's dashboard] and you'd be like, "*Oh, it's not enough*." Or I'll be like, "*Oh, I did pretty good*." Or "*We both did good*." I'll be like, "*Oh, look [child name], this is how much you did.*"

These collective assessments suggest families' desire to assess their capacity to meet the game's objective of more competently engaging in PA.

In conclusion, the data suggests that for our participants, comparisons within a family-based exergame such as SL were seen as positive, in part, because they facilitate opportunities for social interactions that fulfill the need of relatedness. Caregivers indicated that the fulfillment of this feeling is important to maintain their engagement with SL. The caregivers described how they collectively assess their PA performance with the child, which suggests that their engagement with SL was also driven by the desire to feel competent in attaining a physically active lifestyle.

DISCUSSION

Our findings highlight the value of designing systems that help parents and kids to collectively increase PA and reduce prolonged sitting, even if they do not exercise at the same place or at the same time. In our formative study, we identified strong parental support for child activity, but parents were not very active themselves and they infrequently modeled PA—two endeavors correlated with increased child PA [8].We explored how an exergame could support the increase and modeling of PA in a family environment. Our evaluation of SL highlighted the value of exergames for impacting intentions to be physically active. Furthermore, our study identified forms of in-game

competition that participants desired. Unlike competition that is focused on outdoing others, our participants desired comparison through competition. Comparisons were perceived to be motivational when the focus is being connected as a family and being competent in achieving wellness. These values resonate with the SDT's psychological needs of relatedness and competence, needs that are well-fostered in a task mastery climate [22].

Based upon our findings and using SDT as theoretical grounding [28], we suggest that future work explore the design of family-focused, task-mastery exergames. We propose a conceptual framework for designing such games (Figure 2); we hope that this rhetorical tool can motivate future work and highlight potential areas of inquiry. In this framework, game engagement (*i.e.*, the desire to play) is driven by two factors (additional factors are potentially salient, we highlight those that arose in our analysis). First, engagement is driven by the goal of being competent in attaining an active life. Our participants regularly monitored their competence by checking their SL dashboard to see how much fuel they acquired and how active they were. This system interaction suggests that the pursuit of competence contributed to participants' desire to use the system. Second, engagement is supported by the satisfaction of relatedness between family members or across families (*i.e.,* feeling connected to and accepted by others). Familial bonding may already be present and this may provide an incentive to play a game that further affirms this bonding. However, our participants also saw the potential of playing family-based exergames to spark family-centric interactions, which suggests the desire for increased bonding between family members. Our participants were in favor of parent-child competition in exergames in large part because they viewed it as a catalyst for family social interaction. Stated differently, they felt that competition could help fulfill their desire for relatedness—feeling connected to others.

When considering the design of exergames, opportunities for positive interactions within a family may be limited if the social environment places too much emphasis on egoistic victories. For example, if a game is designed such that one or more players will win *over* other players, someone in the family may be identified as the weaker player. With such a hierarchy, feelings of shame or disappointment could hinder positive interactions such as discussions about how the family can better achieve its PA.

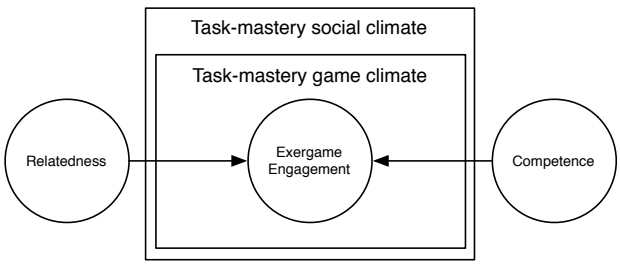

Figure 2. Task-mastery Exergame Framework

In support of this hypothesis, prior work has argued that a *task-mastery* PA climate (as opposed to an *ego climate* that focuses on winning over other players) helps nurture feelings of competence and relatedness, which are correlated with self-determination to engage in PA; ego climate is not correlated with increased self-determination [22]. Therefore, competition in exergames may be best facilitated in a task-mastery environment that nurtures relatedness and competence over outdoing others.

Given this prior work, we propose the design of exergames that help players focus on achieving the game task, versus beating others. Furthermore, given that the social dynamics of the family have important influences on behavior, we suggest that any game designed for play in this environment carefully consider the influence of the family social climate. Based upon this conceptualization, we suggest four design implications for family-based exergames.

Recognize individuals' efforts and value family as a unit

Our findings suggest that participants desired the satisfaction of relatedness and competence during SL game play. Within the SDT framework, a task-mastery climate values individual and group efforts rather than outdoing others, because it nurtures the feeling of relatedness and competence [22]. Therefore, we propose that family exergames should be designed such that the PA efforts of individual members are recognized and celebrated as positive pursuits of a healthier life. Such recognition may be a valuable way of nurturing the feeling of relatedness because it maintains the feeling of acceptance by not excluding the weaker players from the rest of the family. It can also help prevent the feeling of competence from being weakened by peer comparisons. Furthermore, the game should encourage family members to support one another, so that the family can be healthier as a unit, as proposed by Grimes *et. al* [12]. For example, when player's game performance is shared, a beneficial approach may be to emphasize family progress towards meeting the recommended PA level, rather than ranking who exercised the most. And, when individuals' PA is displayed comparatively, the game should highlight how family members could encourage one another to be healthier.

Exergames that leverage personal health monitoring could also be designed so that family members are made aware when others are physically active or meeting their target. For example, an activity tracker wristband might vibrate to let a parent know when their child is active. In turn, the parent could reply by sending a vibrating pulse to the child's wristband, conveying motivational support. Long-distance couples communicating through a similar tool felt the device facilitated stronger feelings of closeness [16].

Design competition that spurs social interaction

Given that a task-mastery environment prioritizes the accomplishment of the game task (*e.g.,* improving one's PA levels) and not beating other players, the inclusion of competitive features in such environments must be

carefully considered. Our findings suggest that comparisons in a competition can be desirable if they promote increased social interaction. Future work should explore how competition can be framed not as a way of winning over others, but as a catalyst for positive social interaction and fulfilling the need of relatedness. This is a particularly important consideration for individuals who are motivated to exercise not because they find it intrinsically enjoyable, but when PA is "prompted, modeled, or valued by significant others to whom they feel (or want to feel) attached or related" [28]. Games may be designed to motivate these individuals by guiding players to discuss health topics and to engage in team-based physical activities, using comparisons solely as an outlet for such interactions. For example, in the next iteration of SL, when a parent's PA is lower than her child's (or vice versa), the game could help players imagine and implement creative ways of helping one another to be more active. Such prompting could motivate families to meet target PA levels.

Recognize the pursuit of relatedness

As discussed previously, task-mastery climate is correlated with the satisfaction of relatedness. Our participants preferred to play with individuals or families with whom the barriers to feeling related are reduced. They described wanting to play SL with their own family members, familiar families, and new-acquaintance families who share similar characteristics, such as a comparable family structure (*i.e.,* similar number of parents and child) and routines (*e.g.,* similar PA frequency). To implement this design implication, a feature could be added to the next iteration of SL so that two families with similar PA patterns are matched and their PA levels compared. When one family's PA level is low, the game could automatically encourage that family to ask the other family for PA ideas. This feature could promote health-oriented interactions and simultaneously satisfy the need for relatedness.

One of our participants also suggested that family-based PA tracking systems might be a valuable way to help families bond, even if they are constrained by time and work. These tools can help facilitate a beneficial outcome (bonding), even amidst the barriers to joint exercise that families face [36]. Presenting family members' PA time series data, for example, side by side can help them understand each other's routine. Such increased understanding may help families to form stronger bonds. To implement this design implication, the next iteration of SL could be expanded with a more detailed and child-friendly view of the family members' activities during the day. This detailed view could be made child friendly by dividing the daily timeline into time spans labeled "morning", "work/school", "lunch", "afternoon", etc. When the child's activity is low (or high) during a particular time span, the game could prompt the parent to ask the child what they were doing at that time. The same approach could be applied to the parent.

This type of system has the characteristics of a socially translucent system that supports visibility, awareness, and accountability [10]. In a socially translucent system, individuals become aware of their actions because socially significant data is visible to everyone, and as a result they are aware that other family members are apprised of the actions they choose [10]. In a PA tool that is socially translucent, family members may become aware that their physical activities are visible to others, and they are held accountable for their activity and inactivity. For example a parent might become encouraged to exercise during her lunch hour so that her children can see that she is physically active. Or, a parent who did housework during the day may feel the effort is recognized because his children and partner would be able to see his activity. Family members could also use the PA timeline as an impetus for sending motivational feedback. For example, when activity is low, families could send a caring message and offer support.

While these design ideas are common in social health monitoring tools, in a family setting they may cause a conflict of competing values, such as caring, openness, and modeling [12]. Prior work by Grimes *et al*. [12] suggested that while parents want to model healthy behaviors for their child, they are concerned that seeing their unhealthy behavior could cause the child to worry. Openness also raises privacy concerns. Parents and children may not feel comfortable having the entire family see their activity data, especially as viewers could potentially infer the kind of activity being done. As such, PA monitoring and information sharing in the family can quickly transition from health promotion to surveillance. This concern is supported by prior work emphasizing the need to balance "control over data versus the feeling of surveillance" [37]. Future work should examine how to balance the opportunities and potential benefits of collective PA monitoring as a means of fulfilling the relatedness need (through the enabling of support, nurturing, and bonding) with emergent privacy concerns.

Examine the interplay between family social context & exergame environment

One participant raised an important concern regarding how the particular social dynamics within a family could impact how competition is received. Indeed, prior work has argued that health interventions should be designed to reflect an understanding of household norms, practices, and attitudes [14]. This highlights how the effectiveness of, and reaction to a task-mastery game depend on the larger social family context in which the game resides. If a family places more emphasis on outdoing others, for example, then the task-mastery game climate may be weakened. To reinforce the that value of collaborative effort, SL could be expanded by providing motivational messages to remind family members that they are playing as a team. For example, when the family's PA is low, SL could encourage them with this message: "Your family is not as active as yesterday. Can you think of how you can become more active as a family?"

Future work should examine how exergames can promote task mastery within the encompassing social system. In particular, further research is needed to understand how variations in factors such as parenting style, communication norms, and household routines interact to support or inhibit PA promotion within exergames. For example, future work might explore how task-mastery environments can be designed for maximum effectiveness in families with an *authoritarian* parenting style (where parents prohibit and enforce activities, disregarding child preferences) versus an *authoritative* style (where activities are encouraged but the child is able to choose amongst presented options). One direction would be to design games that resonate with existing parenting styles; another would be to help parents consider alternative parenting approaches that research has shown more effectively encourage child wellness.

LIMITATIONS AND FUTURE WORK

Our work focused primarily on caregivers' perspectives on PA, SL, and the potential for family-based exergames. Exploring such perspectives is critical to the design of these tools; future work should further investigate the complimentary and equally important perspective of the child. It should also be noted that a majority of the participants are female, reflective of the demographics of the gym program we recruited from. However, future work should further examine the perspective of male caregivers to unpack potential gender differences in the context of family-centered exergames. Taking such a gender-sensitive approach will be critical for understanding how to effectively engage different family members in technology-based health interventions. In addition, we studied exergames in the context of a two-member team. Future work should examine how an entire family might work together in an exergame context. For example, researchers should carefully explore issues of sibling rivalry that may emerge, to help avoid potentially undesirable outcomes.

Our participants were community gym attendees who are informed about the value of PA. Future work should examine how systems can be designed for families who are in the pre-contemplative stage, that is, not yet thinking about increasing PA. Future work should also compare the efficacy of exergames to other health education efforts (such as informational workshops) in instilling healthy PA behavior. In addition, building on work by Mandryk *et al.*, [19], a potential direction for future work is to explore how family exergames can not only target MVPA (as in SL), but support anti-sedentary behavior more broadly. Finally, larger, longitudinal studies are needed to further validate our findings and explore how games like SL are used over time as well as their impact on behaviors.

CONCLUSION

Our work has explored how technology can promote PA in the family context, as prior work has shown the important influence of the family on behaviors. Through a formative study, we identified the opportunity for task-mastery exergames to facilitate increased parental modeling of PA. While we designed SL to be collaborative, participants expressed nuanced desires for comparison in competition, particularly as a means of achieving relatedness and competence. These findings suggest the value of a task-mastery climate for nurturing exergame engagement. Accordingly, we presented a set of design recommendations for future work on family exergames. In addition, our preliminary results point the potential efficacy of this game. Therefore, we encourage future work to examine how family-focused exergames can be designed as task-mastery environments. We hope that our design recommendations will spur further research in this area.

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