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Effects of Home-Based Exergaming on Child Social Cognition and Subsequent Prediction of Behavior

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Abstract

The use of exergames may be one viable way to increase child physical activity, but investigation of its effects on motivation over time, and prediction of adherence has seen little research attention. The purpose of this study was to compare the effect of two cycling exergame interventions (single-player, multi-player) among children aged 9-12 years on motivational variables (theory of planned behavior) and to explore whether these variables could predict objective assessment of play time across six weeks. Sixty-nine insufficiently active children were recruited through advertisements within the community/schools and randomized to either the single play condition (n = 30) or multi-player condition (n = 39). Exergaming use was recorded objectively via game logs and motivational variables were assessed after a familiarization session, at two weeks, and at four weeks. Participants played the exergames *M* = 133.45 (*SD* = 81.27) min in week 1 to *M* = 77.23 (*SD* = 84.09) min in week 6. The two exergame conditions did not result in differences among theory of planned behavior variables ($p > .05$). Mean levels of these constructs declined across the first four weeks ($p < .05$), with the exception of injunctive norm. Positive bivariate associations ($p < .05$) between game play and perceived control (zero to six weeks), and intention (weeks 3-4 and weeks 5-6) were identified, but only affective attitude (assessed at week 2) predicted ($p < .05$) game play (3-4 weeks) in a multivariate examination of the theory of planned behavior model. The results demonstrate that social cognitive motives wane across time when exposed to repeated exergame play.

Key Words: Physical Activity, Exercise, Affective judgment, Perceived behavioral control Theory of planned behavior, Intervention, Family

Regular physical activity and high physical fitness protect children against high blood pressure, high blood cholesterol, metabolic syndrome, low bone density, depression, and obesity [1]. Furthermore, childhood physical activity may form the behavioral patterns necessary for health benefits across the life course such as the reduction of several health conditions including breast cancer, colorectal cancer, cardiovascular disease, stroke, type 2 diabetes, osteoporosis, and mood [2]. Unfortunately, few youth in developed countries are sufficiently active to reap these benefits [3], suggesting that promotion efforts are paramount for public health.

The family home also offers a critical setting for increasing child physical activity [4,5]. Despite this obvious aperture for promotion, results of family-based home interventions have been mixed and relatively understudied [4,5]. One area of home-based physical activity that has seen recent attention is in the use of exergames. Exergames, such as those played on the Nintendo Wii™, Microsoft Kinect™, or cycle ergometers are games where players engage physically (using leg, arm, or whole-body movement) in response to some on-screen virtual activity. Evidence suggests that these games can significantly increase energy expenditure, although this is highly dependent on the type of game and console used [4-6]. Exergames also have extensive reach into the homes of youth, suggesting massive potential with regard to intervention scalability. For example, over 101.63 million units of the Nintendo Wii have been sold since its introduction and has contributed to a 73% increase in net Nintendo sales with Wii sports as their highest selling product [7]. Exergames for Wii/Wii U and Kinect continue to dominate many of the top sales figures since their release [8].

From a physical activity motivation standpoint, exergames may also influence some of the key mediators of behavior change. They offer an inexpensive, safe and controlled experience in the family home that can alleviate the fears that many parents have, whether real or imagined,

about outdoor neighborhood play [9]. They can also overcome some of the barriers of inclement weather that are viewed as barriers of child physical activity because exergames are played indoors [10]. This approach also offers a solution to physical activity where land density limits outdoor opportunities. Thus, exergames may promote a sense of control or self-efficacy [11].

Entertainment-based exergames are also designed to impart motivation in the form of high affective expectations or judgments (expected pleasure, enjoyment, intrinsic regulation). Affective judgments are a central construct – in some form - in many popular health behavior models (e.g., self-determination theory, theory of planned behaviour, social cognitive theory) and show a clear link to child physical activity [12]. The effect of exergames on affective judgments in youth also has strong validation, particularly under short-term exposures. For example, exergames have been identified as more enjoyable than traditional forms of exercise [13-15].

While the effects of exergames on key potential mediators of youth physical activity is promising, there are considerable limitations to the extant research. Most notable is the disconnect between studies that show short-term effects of exergames on affective judgments, yet home-based behavioral trials show negligible sustained use. Indeed, almost all home trials show high use of exergames over a short duration (e.g., first few weeks), but significant declines in the first six weeks [4-6]. No studies have reported on the predictors of exergame play. Clearly these analyses are necessary to chart the *mechanisms* that may be responsible for use across time.

Furthermore, there is some evidence that initial impressions of exergames, such as social cognitive perceptions, are not accurate reflections of longer term exposures, where enjoyment and intentions appear to decline [13,16]. This is problematic given that most of the studies of exergame social cognition involve single exposure designs [17]. From a theoretical perspective, initial impressions of exergaming may be a product of response shift [18], where the brief exposure

to the stimulus is not an accurate impression of longer-term play, which is arguably a better indicator of one's true social cognition about a target behavior. Assessment of perceptions about exergaming across time is needed for a better understanding of the motivational processes underlying its use.

Thus, the purpose of this study was to follow-up on a previously published non-randomized six-week trial focused on the objective assessment of exergame recumbent cycling among children aged nine to 12 [19]. This trial reported on a comparison between online multi-player exergaming and the same games with a single-player only condition. There was no significant difference between these conditions, but exergame playtime was high (*M* = 133.45 min per week in week 1 to M = 77.23 min in week 6), though it had large variability (*SD* = 81.27 min in week 1 to *SD* = 84.09 min in week 6). The purpose of this follow-up paper is to 1) examine the effects on intermediary social cognitive variables, and 2) predict exergame use over time. This study used the theory of planned behavior [20] as a social cognitive framework to understand bike use. The framework has been applied to a small number of studies to understand exergame play [16,21,22] and has shown predictive capability when explaining physical activity among children [23,24]. Briefly, the theory of planned behavior suggests that intentions are the primary cause of behavioral action with intention subsequently determined by affective (pleasure) and instrumental (utility) attitudes, injunctive (perceived social expectations) and descriptive (perceived behavioral actions from others) norms and perceived behavioral control (capability and autonomy) over enacting the behavior.

The first purpose of the study was to explore whether the different exergame conditions had an effect on theory of planned behavior constructs. Though there was no effect of condition on play behavior [19], social cognitive constructs are positioned as intermediary motivational

variables and may be able to demonstrate some differences in exposure to the multi-player or single player conditions. We hypothesized that participants in the multi-player exergame condition would report higher affective attitude and intention compared to the single-player condition, given the more immersive potential experience of playing with others [25]. The second purpose of the study was to explore the stability of social cognitive perceptions of exergame play across the trial. Based on prior research, we hypothesized that motivation may wane across time as the exergame experience becomes less novel [13,16]. Finally, the third purpose of the study was to explore the correlates of bike use in both conditions across time, given there was no noteworthy difference in use across conditions but considerable variability in use between participants [19]. Based on prior theory of planned behavior research, we hypothesized that bike users would have stronger intentions, affective attitudes and perceived behavioral control.

Methods

Methods and primary outcomes from this study have been published in full elsewhere [19].

Design

The trial employed a two-arm, nonrandomized control trial design. One group received the multi-player online exergame condition and the other group received the single-player condition. Assessors were not blinded, and participants and parents were not blinded to study condition given the characteristics of the study. The study consisted of five waves of six-week trials that ran, in two sites, from January 2014 to December 2014. During each wave, the two sites trialed opposing conditions (i.e., when participants in the first site were in the multi-player condition, participants in the second site were in the single-player condition). Prior to study commencement, the trial was registered at www.clinicaltrials.gov (identifier NCT02032667).

Participants

Participants were recruited using advertisements placed at elementary/middle schools, cub scouts/brownies, recreation centres, health care centres, children's recreation classes, shopping malls, and online sites Facebook and Kijiji. Additional recruitment occurred via snowball sampling, in which families of previous participants were offered a $25 CAD honorarium if they could recruit additional families to the study. Participants were children between 9 and 12 years old, who were not meeting physical activity guidelines [26] as measured via the physical activity questionnaire for children [27], and did not report having a developmental disorder or disability. Children aged 9-12 were chosen because this is an age in which children can physically use the bikes [28]. In addition, the exergames were designed for a late elementary school level and would not be as suitable for a mature audience.

Study settings. Participants were recruited in either the greater Victoria, British Columbia or Kingston, Ontario regions.

Intervention

Both conditions used the Liberi exergame system, originally developed using a participatory and iterative design approach to provide a moderate-to-vigorous intensity exercise stimulus for children with cerebral palsy [29]. Liberi contains a central plaza (island) that gives access to six different mini-games. The games are balanced to support differing player abilities and to support a variety of play styles. To promote long-term adherence, the central plaza also contains shops where players can purchase costumes for their avatars and upgrade their weapons using coins collected by playing the games.

Participants played games using a Microsoft Surface Pro 2 tablet that was attached to a Vision Fitness R10 recumbent bike. A YEI Bluetooth Sensor was attached to one of the pedals of the bike and sent gyroscopic data to the games in order to make in-game characters move. To

control the direction of characters and perform in-game actions, participants used a Logitech F710 wireless gamepad. In order to talk to other players and hear in-game audio, participants wore a Logitech wireless headset while playing. Participants also wore a Garmin Soft Strap Premium Heart Rate Monitor, which sent heart rate data to the games.

In the multi-player condition, participants played against or cooperated with each other, connected by a network from home and speaking to each other using headsets. In the single-player condition, participants only played against or cooperated with artificial intelligence opponents. During each play session, game monitors (i.e., research assistants) were available to participants to troubleshoot any issues that players had with hardware or software, to log significant gameplay events (e.g., which players were playing what games), and to ensure children were not acting or speaking to one another in an inappropriate manner. Game monitors were not permitted to play the games with the children.

Measures

Exergame Play**.** Play session logs were used to calculate play duration. The logs recorded every second of play, measured objectively using a sensor that determined whether a player was pedaling the recumbent bike. Weekly play duration was determined by accumulating the number of seconds of play recorded by the logs. Any interruption in play, such as if a child had played, stopped playing, and played again within the same session was not accumulated in the calculation of play duration because the cadence sensor was not active during this interruption. For the purpose of these analyses, play duration was broken into 2-week epochs (0 to two weeks, two-weeks to four-weeks, four-weeks to six weeks).

Theory of Planned Behavior Variables. Predictor variables of bike use included social cognitive constructs from the theory of planned behavior [20]. The instrumentation used to assess the

constructs of the theory of planned behavior has been previously validated for stationary bike exercise [16] but the response options provided to these questions were modified to those that that have been used with children [24]. All measures followed the instructions and suggestions of Ajzen [30]. Questions were framed in terms of expectations of bike use over the next two weeks. The frame of reference for bike use in these questions corresponded to 4 days per week of 30 min or more at a moderate intensity, to represent an approximation of what might be available during the weekly blocked time for play (see Procedures). *Affective attitude* (enjoyable, pleasant, exciting) and *instrumental attitude* (useful, wise, beneficial) were measured with three items on four-point scales (extremely, moderately, slightly, not at all). *Subjective norm* was measured with three items comprising the injunctive (most people who are important to me would want me to…, most people whose opinions I value would expect me to…, I feel pressure to….) and one item comprising the descriptive (most people who are important to me will…) norm component of the concept. Four-point response anchors were used to rate these items from 'disagree in a big way' to 'agree in a big way'. *Perceived behavioral control* was measured with three items through the response options of four-point scales between 'disagree in a big way' and 'agree in a big way'. Assessment of perceived behavioral control included both of its components of capability (confident I can…) and autonomy (under my control, up to me…), with a phrase to hold motivation constant (i.e., if I really wanted to) in order to reduce any confounded assessment of motivation. Finally, intention was measured with two items (I plan…., I intend…) using four-point response anchors from 'disagree in a big way' to 'agree in a big way'. Measures of affective attitude (time 1 $\alpha = 0.81$; time 2 $\alpha = 0.84$; time 3 $\alpha = 0.90$), instrumental attitude (time 1 $\alpha = 0.68$; time 2 $\alpha = 0.74$; time 3 $\alpha = 0.90$), subjective norm (time 1 $\alpha = 0.66$; time 2 $\alpha = 0.78$; time 3 $\alpha = 0.81$), perceived behavioral control (time 1 $\alpha = 0.64$; time 2 $\alpha = 0.64$; time 3 $\alpha =$

0.72) and intention (time 1 $\alpha = 0.89$; time 2 $\alpha = 0.86$; time 3 $\alpha = 0.89$) showed adequate internal consistency.

Procedures

Prior to study commencement, parental consent and child assent were obtained. Participants completed the Physical Activity Readiness Questionnaire for Everyone to screen for pre-existing health conditions that might be exacerbated with exercise [31]. Once deemed eligible to participate, an orientation session was held at the participant's home, which included the delivery of a recumbent bike, tablet, game controller, and the Liberi game. The parent or guardian then completed a demographics questionnaire and assisted the child in completing the Physical Activity Questionnaire for Children [32]. Assessment of the theory of planned behavior constructs was performed after the initial orientation session, and at the two week and four week points of the trial (via home-based collection by research assistants).

Open session exergaming took place 5 days per week for 90 min in the early evening with online monitor supervision. Participants played the game for six weeks. In both conditions, the games were open for an hour and a half block of time each weekday, scheduled at a time that was agreed upon by all families during orientation. The games were only available to play during this time. Two games were initially available to play during the first week of the trial. To foster motivation, a new game was released on weeks two, three, four, and five. By the sixth week, there were six mini-games available to play. The order and timing of which games were offered was standardized across study conditions and locations. The participant was told to play the game as frequently as they could.

Compliance with Ethical Standards

The University of Victoria Human Research Ethics Board and Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board approved the study and the authors had no conflicts of interest to disclose. All participants provided informed consent to participate in the study.

Statistical Analysis

Data were analysed in SPSS 20 (SPSS Inc., Chicago, IL, USA). Normality of all variables was checked to determine whether any transformations were required. Descriptives and bivariate correlations of all variables were then computed. Repeated measures analysis of variance of time (baseline, 2 weeks, 4 weeks) by condition (single-player, multiplayer) was explored for all theory of planned behavior constructs. Prediction of bike use with the theory of planned behavior included the week 1 to week 2, week 3 to week 4, and week 5 to week 6 epochs of bike use. This approach directly aligned with the questionnaire phrasing that asked participants to think about use of the bikes over the next two weeks, as we assessed these concepts on the orientation day, week two, and then again at four weeks into the trial. Ordinary least squares regression analyses with path analysis were used to predict the effect of condition (multi-player, single-player) on the constructs of the theory of planned behavior and subsequently predict these constructs on bike use. Further, the PROCESS macro for SPSS [33] was used (5000 bootstrapped samples) to investigate any mediation effects of the theoretical constructs between bike condition (multi-player, single-player) and bike use if needed as well as provide 95% confidence intervals of all estimates.

Results

Participant Flow

Study flow of participants (see Figure 1) has been presented previously [19]. Ninety seven children were assessed for eligibility and 72 participants met inclusion criteria. The distribution between Kingston (n = 40) and Victoria (n = 32) sites was relatively equal and the single-player bike group included 32 children while the multi-player bike group included 40 children. Two participants were lost to drop-out (1 = frustration from bike not working; 1 = unhappiness with the family's need to modify the home for the experiment). An additional participant did not complete any of the questionnaires for the study. These three participants were not included in analyses.

Baseline Characteristics of Respondents

Detailed baseline characteristics of the participants are reported in the prior publication [19]. Children had a mean age of 10.28 years (SD = 0.98), 37.5% were female, 89.7% were White, and over 80% were regular videogame players who watched an average of two hours of screen time per day. On average, the children reported doing less than 1-2 bouts of PA over the past week at baseline. BMI z scores suggested that 92.8% of participants were within the normal weight range, 5.8% were in the overweight range, and 1.4% were in the obese range [34]. Demographics were not different across the experimental and comparison condition ($p > .13$).

Handling Missing Data and Normality Assumptions

The aggregates of 0 to 2 weeks, 3 to 4 weeks, and 5 to 6 weeks bike use data were normally distributed with no missing data. Specifically, on every query performed, the possibility of missing data due to technical glitches was taken into consideration by not including log entries that had consecutive timestamps twenty seconds or greater apart. All theory of planned behavior constructs were also normally distributed, but two (3% of the sample) participants had missing data on the theory of planned behavior constructs at the second

assessment (2 week point) and three participants (4% of the sample) had missing data at the third assessment (4 week point). These data were found to be missing completely at random for both the second [Little's test (51) = 56.20; p = .29] and third assessment [Little's test (27) = 28.394; p = .39]. Still, a more specific analysis of dummy coding a "missingness" variable showed that missing data at the second assessment were associated with lower play time (r = -.26; p = .03) during the first two weeks, while missing data at our third assessment were associated with being a girl in the study (r = .27; p = .02). Based on the complexities of these associations, particularly the association between missing data and lower play time behavior, we did not undertake a data imputation approach [35,36].

Exergame Play and Theory of Planned Behavior Constructs

Descriptives and bivariate correlations among the theory of planned behavior constructs with bike use can be found in Table 1. Repeated measures analyses of variance showed that affective attitude ($F_{2,61} = 10.71$; $p < .01$; $\eta^2_{partial} = 0.26$), instrumental attitude ($F_{2,61} = 3.55$; $p = .04$; $\eta^2_{partial} = 0.11$), descriptive norm ($F_{2,61} = 5.48$; $p < .01$; $\eta^2_{partial} = 0.16$), perceived behavioral control ($F_{2,61} = 3.90$; $p = .03$; $\eta^2_{partial} = 0.11$), and intention ($F_{2,61} = 4.51$; $p = .02$; $\eta^2_{partial} = .12$) decreased from baseline across the two-week and four-week assessments (See Figure 2). No theory of planned behavior construct showed a difference by the single-player and multi-player conditions ($p > .17$). Affective and instrumental attitude, injunctive norm, and perceived behavioral control all correlated with intention ($p < 0.05$). Perceived behavioral control was the only construct that was consistently correlated ($r = 0.26$ to $r = 0.29$) with exergame play ($p < 0.05$), yet instrumental ($r = 0.34$) and affective attitude ($r = 0.36$), injunctive norm ($r = -0.29$) and intention ($r = 0.30$) at two weeks were associated ($p < .05$) with exergame play during the two to

four week epoch. In turn, intention at four weeks ($r = 0.25$) was also associated with exergame play ($p < 0.05$) during the two to four week epoch.

Path Analyses of the Theory of Planned Behavior Predicting Exergame Use

Because condition (single-player, multi-player) was not associated with any theory of planned behavior construct or exergame play, it was omitted from the path analyses and no mediation tests were conducted. Furthermore, basic child demographics such as child age, sex, BMI, video game history and physical activity were not associated with exergame play ($p > .05$) so these factors were not included in the prediction models. Figure 3a details the path diagram for the theory of planned behavior constructs at baseline predicting bike use during the first two weeks. Mean play-time was 245.38 min (SD = 148.12). Only perceived behavioral control predicted intention to use the bikes over the first two weeks ($\beta = .44$; $p < .01$), explaining 28% of its variance. No theory of planned behavior construct predicted bike use during this period ($p > .05$), including a second block in the regression analyses where all theory of planned behavior constructs were freed as paths to predict behavior.

Figure 3b shows the path diagram for the theory of planned behavior constructs assessed at two weeks predicting bike use during weeks three and four. Mean play-time was 207.19 min (SD = 150.26). In this model, affective attitude ($\beta = .29$; $p < .05$), injunctive norm ($\beta = .24$; $p < .05$), and perceived behavioral control ($\beta = .43$; $p < .05$) all independently predicted intention and explained 62% of its variance. In turn, affective attitude ($\beta = .31$; $p < .05$) was the sole direct significant effect on exergame play, explaining 18% of the variance.

Finally, Figure 3c shows the path diagram for the theory of planned behavior constructs assessed at four weeks predicting bike use during weeks five and six. Mean play-time was 168.86 min (SD = 155.00). Like the previous two-week epoch, affective attitude ($\beta = .30$; $p <$

.05), subjective norm ($\beta = .30$; $p < .05$), and perceived behavioral control ($\beta = .38$; $p < .05$) all independently predicted intention and explained 55% of its variance. Like the first two-week epoch, no theory of planned behavior construct significantly predicted exergame play during this five to six week period ($p > .05$), including a second block in the regression analyses where all theory of planned behavior constructs were freed as paths to predict behavior.

Discussion

This study compared the effects of two arms of an exergame cycling intervention (single-player, multi-player) among children aged nine to 12 on motivational variables (theory of planned behavior) across six weeks and explored whether these variables predicted exergame play. The first purpose of the study was to explore whether the different exergame conditions had an effect on theory of planned behavior constructs. We hypothesized that participants in the multi-player exergame condition would report higher affective attitude and intention compared to the single-player condition, given the more immersive potential experience of playing with others. Our results did not support this hypothesis. Indeed, no theory of planned behavior construct showed significant differences by condition. The results align with the prior null behavioral outcomes of this trial between the conditions [19], and collectively suggest that the participants were not affected by multi-player capabilities when compared to the single-player condition. Our findings are in contrast to general positive findings from multi-player videogaming when compared to single player variants [37] and only one prior exergame trial that did conclude that multi-player options enhanced the experience [25]. In our study, we suggest two potential explanations for the null findings see also [19]. First, given that we released a new game to play throughout the trial, it is possible this was a larger motivator for both groups than multi-player or single-player capabilities. Second, we may have failed to implement multi-player

capabilities as effectively as possible, thus reducing the advantageous effect of this condition. Multiplayer play is usually due to the establishment of social groups with the other players, however, none of the participants in our study had met before the trial. It is likely that it was more difficult to establish a social group with strangers than it would have been with friends, and the impersonal forms of communication could have contributed to a lack of group cohesion. Future studies may benefit from pre-trial sessions so that participants meet, and become familiar with, one another in person or make use of existing friendships within the design. A more focused assessment of group dynamics indicators (e.g., cohesion) may also be useful in future research.

The second purpose of this study was to explore the stability of social cognitive perceptions of exergame play across the trial, regardless of condition. Based on prior research, we hypothesized that motivation may wane across time as the experience becomes less novel. This hypothesis was supported. Indeed, all theory of planned behavior constructs, with the exception of injunctive norm, showed a significant decline in the large effect size range from baseline to two weeks and then to four weeks into the trial. Affective attitude showed the largest decline over time, suggesting that initial expectations of enjoyment and pleasure were likely positively biased at baseline. The results align with past evidence in exergames [13,16] and are likely from the novelty of early exposures to this form of physical activity. Nevertheless, the results in this study are particularly interesting because we did introduce new games each week in order to minimize over-familiarization [38]. The results suggest that at least some of the initial impressions of exergaming may come from the novelty of the activity and not necessarily the games themselves. From a practical perspective, the findings collectively highlight how initial exposures to exergames may not be the most accurate representation of social cognition over

time so the findings from single-session research designs may not reflect longer-term adherence outcomes [39].

The third purpose of the study was to explore the correlates of bike use in both conditions across time, given there was no noteworthy difference in use across conditions but considerable variability in use between participants [19]. We hypothesized that bike users would have stronger intentions and subsequently higher perceptions of affective attitude and perceived behavioral control. Overall, we had partial support for this hypothesis when examining three prediction periods of play: 1-2 weeks, 3-4 weeks, and 5-6 weeks. Specifically, perceived behavioral control was associated with exergame play across the six weeks in the small effect size range and intention at two weeks and four weeks was associated with play time at three to four weeks and five to six weeks in the small effect size range, respectively. These two variables shared a high covariance, and thus their combined predictive effects in multivariate analyses were not significant predictors of play time. Interestingly, affective attitude at two weeks did predict exergame play at three to four weeks in the medium effect size range, but it was not associated with play at the earlier and later epochs.

The association between bike use with affective attitude is similar to prior research in exergames showing the link between play with high affective judgments [13-15]. The association of exergame play with perceived behavioral control is also similar to some prior trials [11] and may have been pronounced in our study because the participants only had a 90 min window of opportunity each day to play these games. Still, the overall results suggest the theory of planned behavior could account for 7-18% of the variance in exergame play across the six weeks, which is lower than its typical performance [40] and rather poor given the close proximity of assessment (i.e., two week epochs). This low performance does suggest that other theoretical approaches to

understanding play behavior could be useful for future researchers. Furthermore, a more refined examination of competing alternatives to exergame play, such as those used in the sport commitment model [41] would seem useful to examine. There has been some contrarian viewpoints about exergaming and health because the activity could take away from traditional physical activities [6]. An assessment of various alternative behaviors and their motivations within the family system could shed light on the choices made to exergame compared to other activities that children may perform.

It is also interesting to note, consistent with past research [40], that the constructs of the theory of planned behavior did explain intention to exergame well (28% to 62% of variance explained). As hypothesized, affective attitude (week 2, week 4) and perceived behavioral control (baseline, week 2, week 4) were relatively consistent predictors of intention. Injunctive norm was also a predictor of intention, and while not hypothesized, this may have represented certain children who felt using the bike was important to their parents, as children are often regulated by their parents [42]. The results support partial workings of the theory of planned behavior model and its measures to explain intention but show its weakness in failing to predict behavior. This intention-behavior gap is a fairly well-established limitation of the theory of planned behavior [43]. Exploration of models that emphasize action control (i.e., translating intentions into behavior) concepts such as family activity plans, may be a useful approach for future research. Specifically, the failure to link child intentions with behavior may be from the more prominent influence of parental control over child behavior, which may not be accounted for in individual models like the theory of planned behavior.

While this study had considerable strengths such as its longitudinal design, ecologically valid setting, cutting-edge intervention and objective monitoring of behavior, there are

limitations. First, the duration was relatively short at six weeks. A longer window each evening in which children could play may yield even greater discrepancies in play that could be explained through motivation. Second, families in this study reported high education and incomes, and were mainly white. Thus, it remains uncertain how well these results may generalize to lower socio-economic status families and different ethnic backgrounds. Third, there may have been cohort effects across conditions, but we were unable to examine these due to the modes sample size. Finally, the choice of games and exercise equipment used in exergaming studies as well as the methods of data collection (e.g., in home assessments vs. online assessments) may also affect social cognition/adherence and so it remains uncertain how well this study would generalize to different exergame trials.

Perspective

While several studies have investigated the effect of exergaming on physical activity in the home environment, this study was one of the first explorations of the predictors of sustained exergaming. An additional strength of this study was the application of objective play time measurement, as nearly all past exergame studies have used self-reported measures. Our results showed that exposure to the exergame did not result in differences among theory of planned behavior variables, but mean levels of these constructs declined across the first four weeks of play, with the exception of injunctive norm. Thus, social cognitive motives wane across time when exposed to repeated exergame play so single-exposure research designs may not accurately reflect long-term motivation. We also found positive bivariate associations between game play and perceived control and intention, but only affective attitude predicted game play (3-4 weeks) in a multivariate model. The theory of planned behavior, therefore, had mixed utility in explaining exergaming. Future research to understand exergaming may benefit from the

application of models that incorporate a more refined analysis of motivation as well as alternative behavioral choices made by children and their parents during free time.

Figure Captions

Figure 1: Participant flow

Figure 2: Means of theory of planned behavior variables across baseline, two weeks, and four weeks of assessment.

Figure 3: Prediction of bike use with the theory of planned behavior at (A) baseline assessment of theory of planned behavior predicting behavior baseline to two weeks, (B) two week assessment of theory of planned behavior predicting behavior three to four weeks, and (C) four week assessment of theory of planned behavior predicting behavior five to six weeks. Note: slotted lines = $p > .05$; full lines = $p < .05$. Bottom coefficients represent lower and upper limits of 95% confidence intervals.

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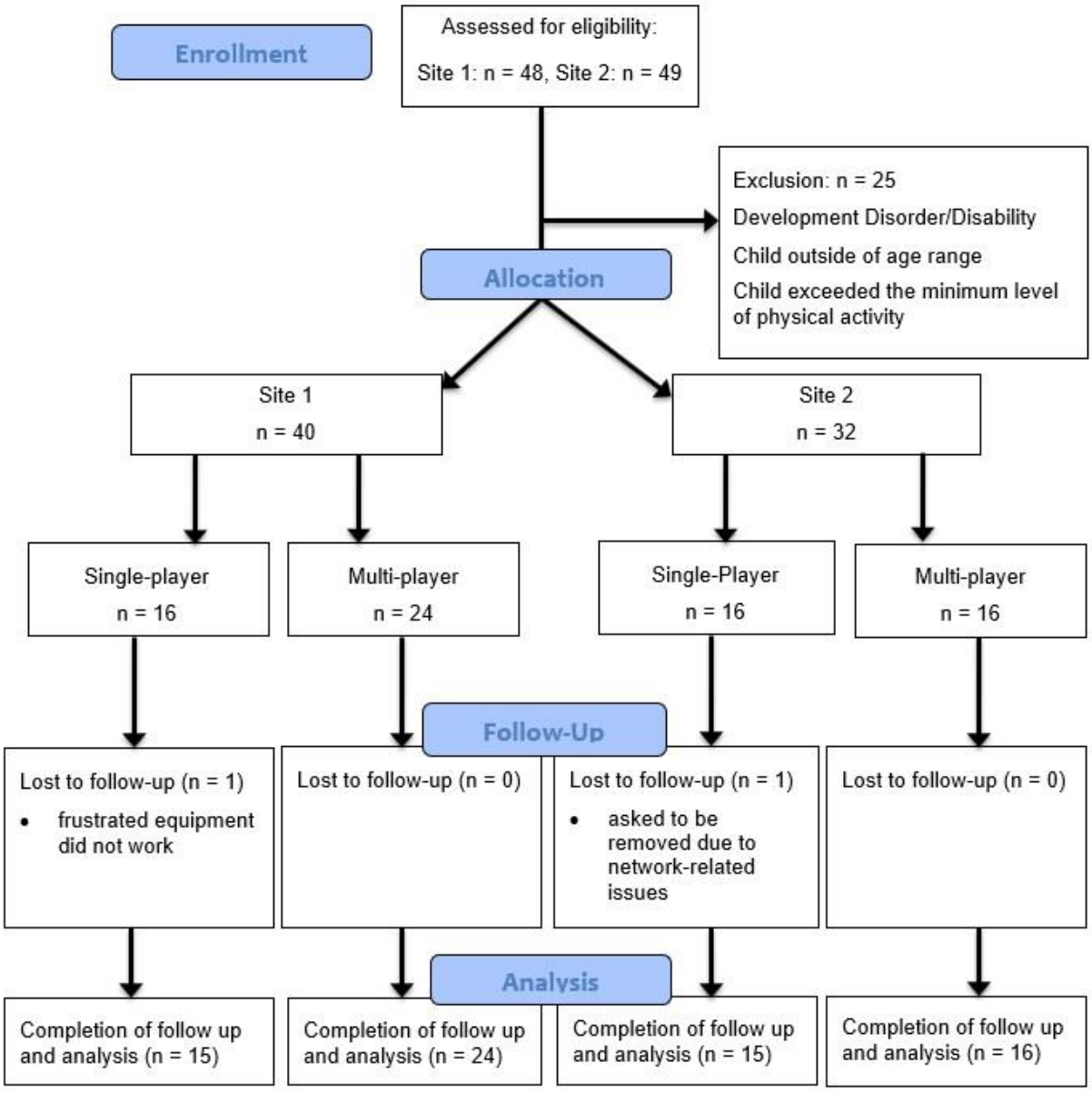
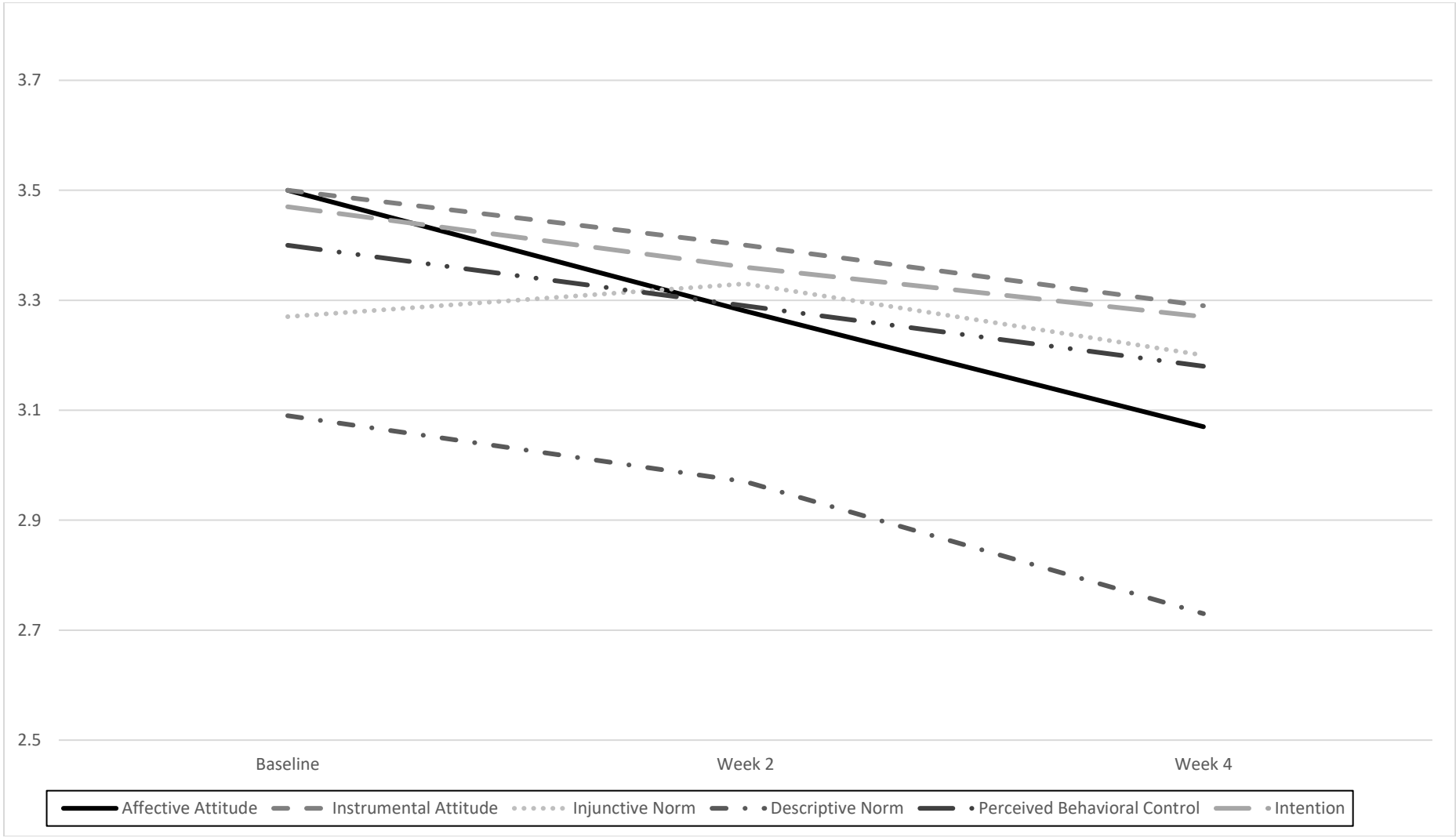
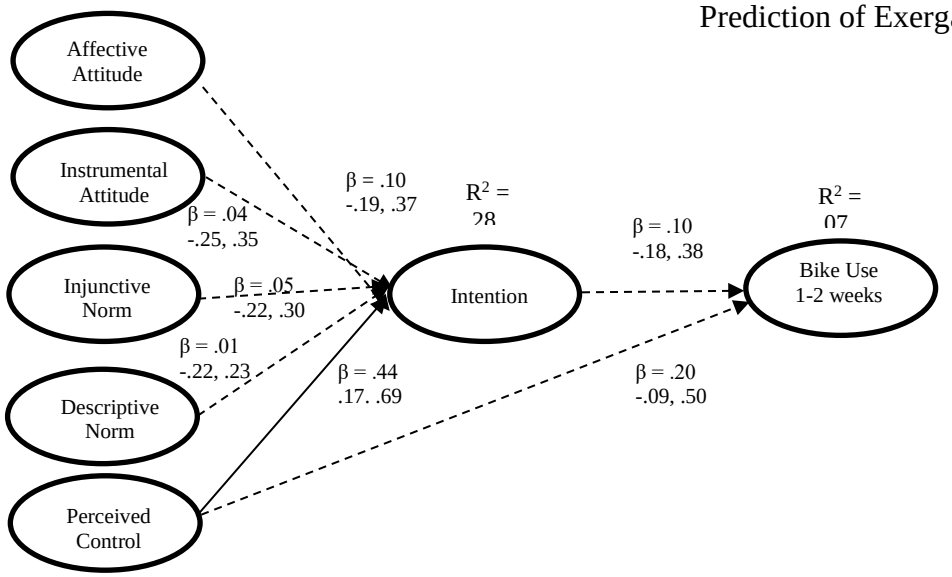
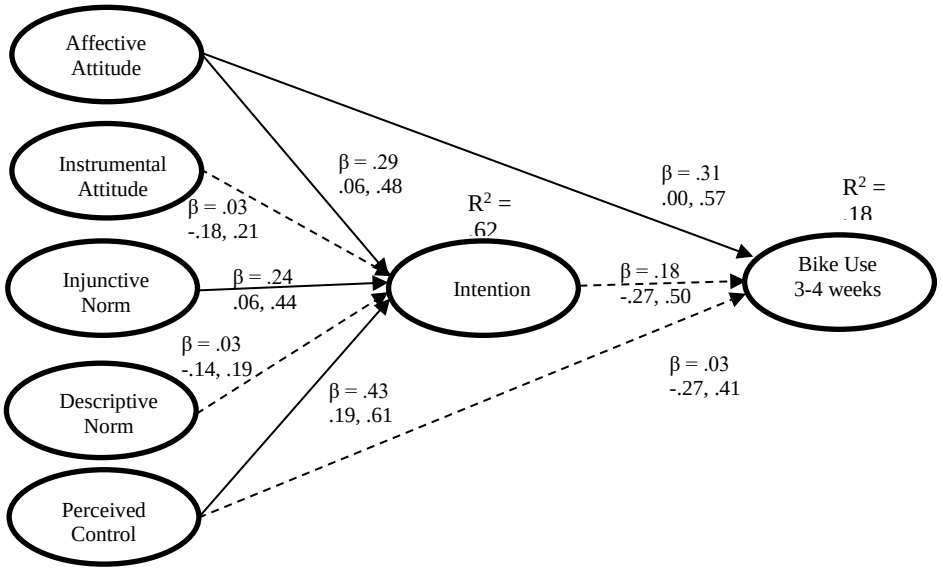

Enrollment
Assessed for eligibility:
Site 1: n = 48, Site 2: n = 49
Exclusion: n = 25
Development Disorder/Disability
Child outside of age range
Child exceeded the minimum level of physical activity
Allocation
Site 1
n = 40
Site 2
n = 32
Single-player
n = 16
Multi-player
n = 24
Single-Player
n = 16
Multi-player
n = 16
Follow-Up
Lost to follow-up (n = 1)
frustrated equipment did not work
Lost to follow-up (n = 0)
Lost to follow-up (n = 1)
asked to be removed due to network-related issues
Lost to follow-up (n = 0)
Analysis
Completion of follow up and analysis (n = 15)
Completion of follow up and analysis (n = 24)
Completion of follow up and analysis (n = 15)
Completion of follow up and analysis (n = 16)


3.7
3.5
3.3
3.1
2.9
2.7
2.5
Baseline
Week 2
Week 4
Affective Attitude
Instrumental Attitude
Injunctive Norm
Descriptive Norm
Perceived Behavioral Control
Intention

A)


Affective Attitude
Instrumental Attitude
Injunctive Norm
Descriptive Norm
Perceived Control
β = .04
-.25, .35
β = .05
-.22, .30
β = .01
-.22, .23
β = .10
-.19, .37
R² = 28
β = .44
.17. .69
Intention
β = .10
-.18, .38
R² = 07
β = .20
-.09, .50
Bike Use
1-2 weeks

B)


Affective Attitude
Instrumental Attitude
Injunctive Norm
Descriptive Norm
Perceived Control
β = .03
-.18, .21
β = .24
.06, .44
β = .03
-.14, .19
β = .29
.06, .48
R² = .62
β = .43
.19, .61
Intention
β = .31
.00, .57
R² = .18
β = .18
-.27, .50
β = .03
-.27, .41
Bike Use
3-4 weeks

C)

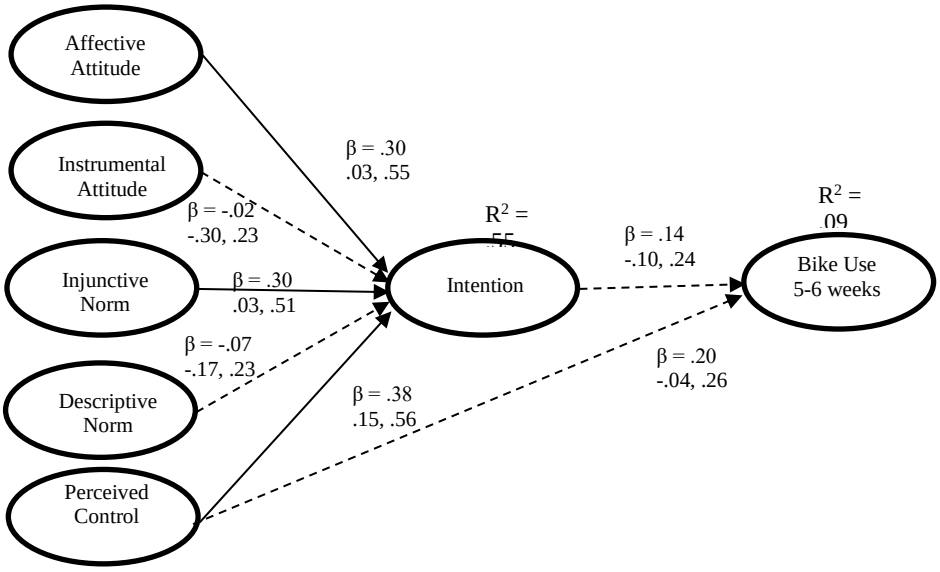

Affective Attitude
Instrumental Attitude
Injunctive Norm
Descriptive Norm
Perceived Control
β = -.02
-.30, .23
β = .30
.03, .51
β = -.07
-.17, .23
β = .30
.03, .55
R² = .55
β = .38
.15, .56
Intention
β = .14
-.10, .24
R² = .09
β = .20
-.04, .26
Bike Use
5-6 weeks

Table 1
Descriptives and Correlations among the Theory of Planned Behavior Constructs With Bike Use

Construct	M (SD)	r with intention	r with exergame play 0 to 2 weeks	r with exergame play 2 to 4 weeks	r with exergame play 4 to 6 weeks
Affective attitude (baseline)	3.50 (0.49)	0.28*	-0.02	0.07	0.10
Instrumental attitude (baseline)	3.50 (0.44)	0.32**	0.09	0.12	0.11
Injunctive norm (baseline)	3.27 (0.49)	0.27*	0.11	0.08	-0.04
Descriptive norm (baseline)	3.09 (0.73)	0.04	0.03	0.02	-.04
Perceived behavioral control (baseline)	3.40 (0.44)	0.51**	0.26*	0.26*	0.13
Intention (baseline)	3.47 (0.55)	NA	0.20	0.28*	0.09
Affective attitude (week 2)	3.28 (0.59)	0.59**	0.23	0.36**	0.24
Instrumental attitude (week 2)	3.40 (0.50)	0.39**	0.25*	0.34**	0.24
Injunctive norm (week 2)	3.33 (0.48)	0.56**	0.00	0.15	0.03
Descriptive norm (week 2)	2.97 (0.75)	0.11	-0.15	-0.25*	-0.22
Perceived behavioral control (week 2)	3.29 (0.45)	0.69**	0.24	0.26*	0.20
Intention (week 2)	3.36 (0.51)	NA	0.26*	0.30*	0.21
Affective attitude (week 4)	3.07 (0.79)	0.61**	0.10	0.24	0.18
Instrumental attitude (week 4)	3.29 (0.68)	0.51**	0.20	0.33**	0.18
Injunctive norm (week 4)	3.20 (0.51)	0.52**	0.17	0.22	0.09
Descriptive norm (week 4)	2.73 (0.81)	0.16	-0.01	0.00	0.01
Perceived behavioral control (week 4)	3.18 (0.51)	0.60**	0.29*	0.29*	0.28*
Intention (week 4)	3.27 (0.48)	NA	0.21	0.33**	0.25*

Note: NA = not applicable. * = $p < .05$; ** = $p < .01$