Health Psychology
2015, Vol. 34, Supplement, 1229–1239

0278-6133/15/$12.00 http://dx.doi.org/10.1037/hea0000302

A Pilot Randomized, Controlled Trial of an Active Video Game Physical Activity Intervention

Wei Peng, Karin A. Pfeiffer, and Brian Winn
Michigan State University

Jih-Hsuan Lin
National ChengChi University

Darijan Suton
Michigan State University

Objective: Active video games (AVGs) transform the sedentary screen time of video gaming into active screen time and have great potential to serve as a "gateway" tool to a more active lifestyle for the least active individuals. This pilot randomized trial was conducted to explore the potential of theory-guided active video games in increasing moderate-to-vigorous physical activity (MVPA) among young adults. ***Method:*** In this pilot 4-week intervention, participants were randomly assigned to 1 of the following groups: an AVG group with all the self determination theory (SDT)–based game features turned off, an AVG group with all the SDT-based game features turned on, a passive gameplay group with all the SDT-based game features turned on, and a control group. Physical activity was measured using ActiGraph GT3X accelerometers. Other outcomes included attendance and perceived need satisfaction of autonomy, competence and relatedness. ***Results:*** It was found that playing the self-determination theory supported AVG resulted in greater MVPA compared with the control group immediately postintervention. The AVG with the theory-supported features also resulted in greater attendance and psychological need satisfaction than the non–theory-supported one. ***Conclusion:*** An AVG designed with motivation theory informed features positively impacted attendance and MVPA immediately postintervention, suggesting that including AVG features guided with motivation theory may be a method of addressing common problems with adherence and increasing effectiveness of active gaming.

Keywords: college student, exercise, exergame, sedentary behavior, young adult

Supplemental materials: http://dx.doi.org/10.1037/hea0000302.supp

Approximately 44% of young adults 18 to 24 years old do not meet the moderate to vigorous physical activity (MVPA) guideline of 150 minutes per week (Centers for Disease Control and Prevention, 2011), despite numerous health benefits of being physically active (Haskell et al., 2007). Sedentary behaviors are linked to all-cause and cardiovascular disease mortality in adults (Tremblay, Colley, Saunders, Heay, & Owen, 2010). The transition from adolescence to early adulthood is a critical time period for establishing lifelong active lifestyles (Bell & Lee, 2005). Unfortunately, few physical activity promotion efforts have been directed toward this specific group. One promising intervention strategy, which addresses both sedentary behaviors and physical activity, is the use of active video games (also called exergames). Active video games (AVGs) decrease sedentary behaviors by transforming the sedentary screen time of video gaming (playing video games while sitting) into active screen time (using actual body movements to interact with the game interface while playing) because the game playing itself is an actual physical activity (Biddiss & Irwin, 2010; Peng, Crouse, & Lin, 2013). A meta-analysis of 18 lab experiments quantifying energy expenditure of AVGs found that playing

Wei Peng, Department of Media and Information, Michigan State University; Karin A. Pfeiffer, Department of Kinesiology, Michigan State University; Brian Winn, Department of Media and Information, Michigan State University; Jih-Hsuan Lin, Department of Communication and Technology, National ChengChi University; Darijan Suton, Department of Kinesiology, Michigan State University.

Darijan Suton is now at University of Massachusetts Boston.

We thank the following individuals for their assistance in data collection: Julia Crouse, Steve Jeong, Mijung Kim, Yumi Jung, Adam Smith, Margaux Hetzman, Sharla Gillespie, and Rebecca Moore. We thank the following individuals for their contributions to the *Olympus* game design and development: Adam Rademacher, Marie Lazar, Jon Moore, Shawn Adams, Adam Starks, Jason Maynard, Jordan Ajlouni, Daniel Alexander II, Michael Hilliker, Daniel Shillair, Bethany Strandbergh, David Phillips, Andrew Dennis, Eric Musser, and Valeta Wensloff. We thank Robert Wood Johnson Foundation for providing funding to support this work through its national program, Health Games Research (Grant 66725). This 2015 special supplemental issue of Health Psychology is supported by funding from the National Institutes of Health (NIH) Office of Behavioral and Social Sciences Research (OBSSR) to support the dissemination of research on eHealth and mHealth interventions, methods, and implications in the practice of health psychology.

Correspondence concerning this article should be addressed to Wei Peng, Department of Media and Information, Michigan State University, 409 Comm Arts Building, East Lansing, MI 48824. E-mail: pengwei@msu.edu

AVG is equivalent to light to moderate physical activity (Peng, Lin, & Crouse, 2011). This intensity of AVGs is appropriate for the least active population to initiate the change from a sedentary lifestyle (Colley, Hills, King, & Byrne, 2010).

Research studies show that in addition to the greater energy expenditure compared to sedentary video games and other traditional physical activities such as treadmill walking, AVGs were better enjoyed (Barkley & Penko, 2009). Particularly, AVGs with greater enjoyment are more likely to be played over time to decrease sedentary behavior (Lyons et al., 2011). AVGs that are more enjoyable and engaging are more likely to produce greater intensity activity (Lyons et al., 2014; Staiano, Abraham, & Calvert, 2012). As activity choice and adherence are largely dictated by the level of enjoyment (Epstein, Beecher, Graf, & Roemmich, 2007), and previous physical activity interventions established enjoyment as a significant mediator (Dishman et al., 2005; Salmon, Owen, Crawford, Bauman, & Sallis, 2003), AVGs have great potential as a physical activity promotion tool among young adults. In addition, digital games are also a receptive tool for the target audience because 81% of young adults 18 to 29 years old are regular or occasional game players (Lenhart, Jones, & Macgill, 2008).

Despite the promising energy expenditure evidence of AVGs, a number of interventions repurposing first generation commercial AVGs for physical activity promotion in children demonstrated suboptimal results because of lack of engagement after the initial weeks of intervention (Biddiss & Irwin, 2010; Maloney et al., 2008). These first generation AVGs were not specifically designed with a theoretical framework for motivation and engagement over time for physical activity promotion. More recent AVGs design with a fitness focus tend to include theory-based behavior change strategies (Lyons & Hatkevich, 2013). To develop more effective AVGs for the least active young adults, special design considerations supported by motivational theories are needed. The current study employed a self-determination theory (SDT) (Ryan & Deci, 2000a, 2000b) informed AVG targeting insufficiently active young adults ages 18 to 24 years, an often overlooked population, for whom AVGs have great potential to serve as a "gateway" tool to a more active lifestyle (Lieberman et al., 2011).

Self-Determination Theory–Guided AVG

SDT assumes that all humans possess three basic psychological needs: the needs for competence, autonomy, and relatedness (Deci & Ryan, 1985). Specifically, the need for competence implies that individuals have a desire to interact effectively with the environment, to experience a sense of competence in producing desired outcomes, and to prevent undesired events. The need for autonomy reflects a desire to engage in activities of one's choice and to be the origin of one's own behavior. Finally, the need for relatedness involves feeling connected, or feeling that one belongs in a given social milieu.

The contexts of an activity can facilitate the satisfaction of the three basic psychological needs and the self-determined regulation process. In the domain of exercise and physical activity, fulfillment of these three basic needs is related to more self-determined motivational regulations. A number of empirical studies have demonstrated the link between positive consequences such as motivation to exercise and exercise adherence and the need satisfaction of competence (Markland, 1999), autonomy (Gagné, Ryan, & Bargmann, 2003; Silva et al., 2010), and relatedness (Edmunds, Ntoumanis, & Duda, 2006).

SDT has also been applied in the game play context. Computer and video game playing is one type of activity that has tremendous appeal, and players are highly motivated to engage in game playing. Ryan, Rigby, and Przybylski (2006) argued that the psychological "pull" of games is largely due to their capacities to engender feelings of autonomy, competency, and relatedness. The features of the gaming environment were found to be the facilitators of psychological need satisfaction and game enjoyment (Ryan et al., 2006). Specifically, games that have considerable flexibility over movement and strategies, choice over tasks and goals, and structured rewards not intended to control the player's behaviors are supportive of autonomy. Game controls that are intuitive and readily mastered, game tasks that provide ongoing optimal challenges and opportunities for positive feedback, and games that enable player to have a sense of accomplishment are supportive of competence. Relatedness may be supported by computer-generated avatars or agents in the game and real players that are connected by the game.

AVGs are a type of video game that require body movements similar to exercise. In active video gaming, similar to what has been found in the domain of sports and exercise as well as nonactive video gaming, features that satisfy players' psychological needs of autonomy, competence, and relatedness, can further lead to increased enjoyment (Ryan et al., 2006), motivation for future play (Przybylski, Rigby, & Ryan, 2010; Ryan et al., 2006), and recommendation intention (Przybylski et al., 2010). Based on the above evidence, the purpose of this study was to examine the effectiveness of an AVG with features that satisfy the need of autonomy, competence, and relatedness. It was hypothesized that an AVG with SDT-supported features would be more effective in reducing overall sedentary behaviors and increasing physical activity (light, moderate, and vigorous) among players during the time that they have access to the AVG and immediately after such AVG intervention is over, compared with an AVG without such need satisfaction features, as well as the control group and the passive game play group. It was hypothesized that the SDT-features-on AVG groups would have greater (a) attendance, (b) time spent on game, (c) need satisfaction of autonomy, (d) need satisfaction of competence, (e) need satisfaction of relatedness, (f) game enjoyment, (g) future game play motivation, and (h) likelihood of recommendation of game, than the SDT-features-off AVG group.

Method

Study Design

This small trial used a four-arm randomized control design with assessment of outcomes at baseline (week 0), week 1 of game play, and one week after game play (week 5). Participants were randomly assigned to one of the four groups: (a) an active gameplay group that employed the active inputs (Wiimote, Nunchuk, and dancepad) to play the game with all the SDT-based features turned off (SDT-features-off AVG group), (b) an active gameplay group that employed the active inputs (Wiimote, Nunchuk, and dancepad) to play the game with all the SDT-based features turned on (SDT-features-on AVG group), (c) a passive gameplay group that used the traditional game controller input (Xbox 360 controller) to play the game with all the SDT-based features turned on (SDT-features-on passive game), and (d) a control group that did not receive any treatment (control group). The passive gameplay group was included to ensure that effects of the game can be attributed to the active gameplay component.

Participants

Inclusionary criteria required participants to be between 18 and 25 years of age, domestic students, playing video games for at least one hour per month, available for week 0, week 1, and week 5 physical activity assessments, and not highly physically active at the time. The total time participants engaged in MVPA in the past seven days was calculated from the screening questionnaire. Time spent in vigorous physical activity was multiplied by two to convert it to time spent in moderate physical activity. Those who reported to engage in no more than 225 minutes per week of moderate activity in total (with the converted vigorous physical activity minutes included) were eligible for participation in this experiment. Among the enrolled participants, only one had more than 150 minutes per week of reported MVPA. Exclusionary criteria were having a medical condition that influenced physical activity or having a seizure disorder. This project was approved by the Institutional Review Board. Table 1 reports the participants' characteristics by group.

Recruitment and Randomization

Participants were recruited in two waves to control for potential seasonal effect as well as to accommodate the limited number of accelerometers, which objectively measured physical activity. Figure 1 illustrates the recruitment procedure and the loss of participants by point after initial recruitment in both waves. Wave 2 resulted in more participants than what could be accommodated by the number of accelerometers and thus some enrolled participants were not equipped with accelerometers. Simple randomization was conducted via computer generated random numbers by the fourth author. Allocation sequence was concealed from the researchers enrolling the participants. Blinding was only possible for the outcome assessors. The participants were provided up to \$100 cash incentives for complying with all the study requirements (e.g., minimal accelerometer wear time, attending orientation and data collection sessions, etc.).

Intervention and Control Conditions

Three versions of an in-house developed game were used. The game was a third person, fantasy role-playing game that allowed players to immerse themselves in the wondrous time of Ancient Greek history and myth. Players could hone their skills and abilities by competing in athletic events and put these skills to the test as they faced challenges from the warring minions of the gods. Through the use of a WiiMote (accelerometer-based motion controller) for upper-body movement and a dancepad for lower-body movement, the player's corresponding physical actions in the real world drove the virtual actions of his or her avatar (player's game world representation) in the game world. For instance, to control the avatar in the game to walk or run, the player needed to literally walk or run in place on the dancepad. To control the avatar in the game to climb, the player needed to physically move both his or her arms and legs in a motion that resembled climbing. In a separate lab experiment (Peng, Lin, Pfeiffer, & Winn, 2012), energy expenditure testing with 150 subjects demonstrated that the average METs/min was 3.5 during 15 minutes of game play. Details of the SDT-based features are described in the Appendix (online supplemental material also include the screen captures of the game). The control group did not have access to the game or receive treatment and only came to the research site for accelerometers and survey completion.

Table 1
Participant Characteristics by Groups

Characteristic	SDT off	SDT on	Passive	Control	Group equivalence
Total N (% within row)	28	34	29	30	
Age	20.32 (1.19)	20.26 (1.44)	20.00 (1.73)	20.13 (1.48)	$F(3, 120) = .28, p = .84$
Gender					$\chi^2(3, N = 121) = 1.59, p = .66$
Female	11 (39.3)	16 (47.1)	16 (55.2)	13 (43.3)	
Male	17 (60.7)	18 (52.9)	13 (44.8)	17 (56.7)	
Race					$\chi^2(9, N = 121) = 5.87, p = .75$
White	23 (82.1)	24 (70.6)	19 (65.5)	24 (80.0)	
African American	4 (10.7)	4 (11.8)	3 (10.3)	2 (6.7)	
Asian	0 (0)	4 (11.8)	4 (13.8)	3 (10.0)	
Other	2 (7.1)	2 (5.9)	3 (10.3)	1 (3.3)	
BMI (kg/m^2)	25.23 (6.36)	24.08 (5.16)	24.07 (4.75)	25.48 (5.02)	$F(3, 120) = .60, p = .62$
Baseline PA (accelerometer)					
% time spent in sedentary activities	71.85 (8.06)	72.39 (8.35)	71.40 (9.19)	71.42 (9.44)	$F(3, 93) = .07, p = .98$
% time spent in light PA	21.53 (7.95)	21.68 (8.86)	21.54 (10.13)	19.70 (11.04)	$F(3, 93) = .25, p = .86$
% time spent in MVPA	6.61 (3.86)	5.93 (4.31)	7.05 (4.91)	8.88 (5.26)	$F(3, 93) = 1.96, p = .13$
Baseline PA (self-report)					
Self-reported MVPA minutes per week	134.11 (115.88)	108.09 (109.24)	109.66 (102.0)	103.00 (103.82)	$F(3, 117) = .48, p = .70$
Self-reported walk minutes per week	10.18 (9.71)	8.94 (8.96)	7.83 (7.37)	11.50 (8.32)	$F(3, 177) = 1.00, p = .40$

Note. Percent in parentheses for gender and race and standard deviations in parentheses for all other variables.

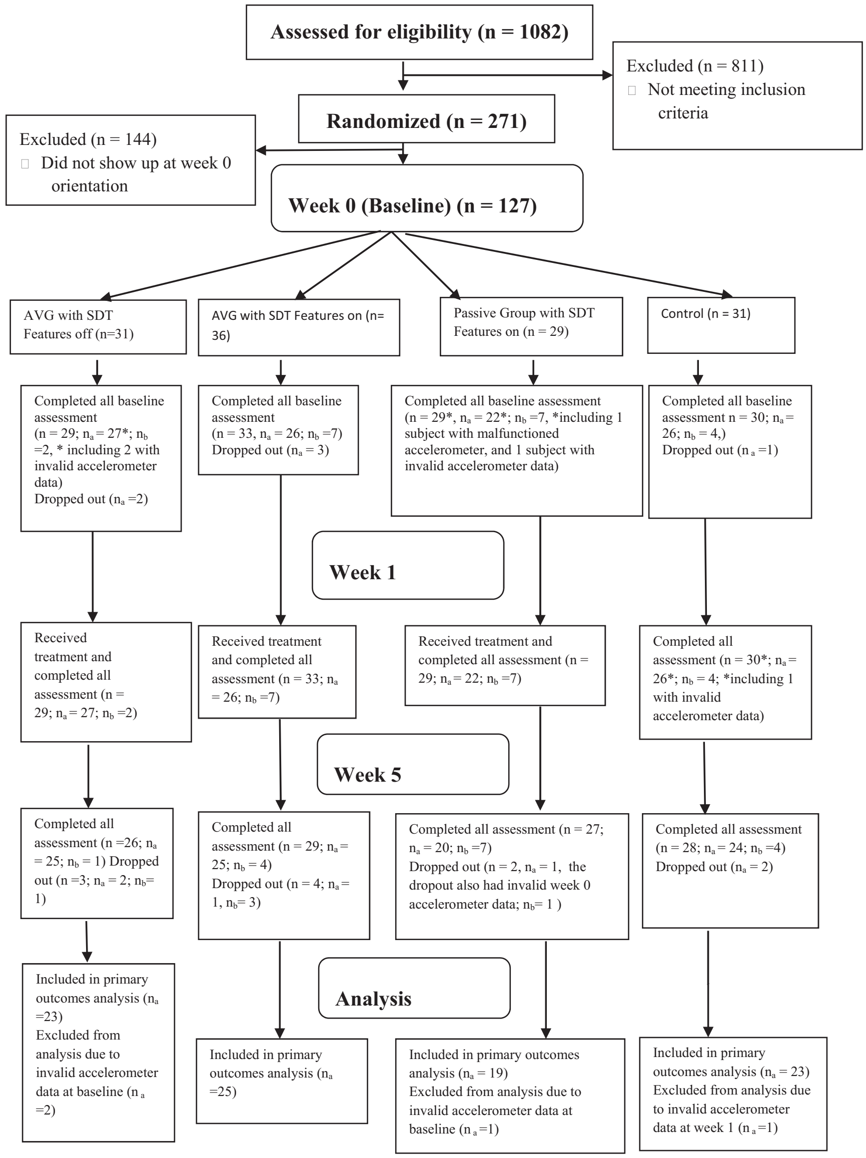

Figure 1. A CONSORT statement figure of loss of participants by point after initial recruitment, Wave 1 (n_a: with accelerometer, n_b: without accelerometer).

Procedure

Recruiting emails were sent to a random sample of 10,000 domestic undergraduate students via the registrar's office at a large Midwestern university at the beginning of each wave (January and March of 2011) and a total of 1,082 responses were received, among which 271 were eligible. Eligible participants were randomly assigned to one of the four conditions and invited to a 1-hr orientation session, which included the consent process, researchers' presentation of the study procedure, final determination of eligibility, enrollment, and training and distribution of accelerometers to be worn for baseline.

One week later, the participants came to the research site and returned the accelerometers. The researchers downloaded and checked the accelerometers. Participants with insufficient or invalid data were asked to additionally wear the accelerometers to make up for any missing data, and/or to fulfill accelerometer wear time requirements. During the weeks that the participants wore accelerometers, at least one e-mail and one text message were sent to all participants to remind them to wear the accelerometers. The participants in all conditions wore the accelerometers at the first week of the intervention and one week after the intervention.

For the participants who were assigned to play the game, at the time they came back for the researchers to check week 0 accelerometer data, they were instructed on the basics of how to play the game. Because the game included a tutorial session, the instruction session was brief. The participants also used an online scheduling system to sign up for time slots to come to the research sites to play the game. The online scheduling system sent automatic reminders for their scheduled game play appointments. The research site had six systems available in six different rooms. The participants were asked to schedule three time slots in a week. The research site was staffed with at least one research assistant for technical support, survey implementation, and distribution of incentives at the end of each week.

Primary Outcome Measures

Total daily physical activity was measured with the ActiGraph GT3X (triaxial) accelerometer (ActiGraph; Pensacola, FL). The monitors were initialized to save data in 1-s intervals (epochs). Participants were instructed to wear the accelerometers on an elastic belt on the right hip (anterior to the iliac crest) during all waking hours for one week at baseline, week 1, and week 5. For analyses, participants must have had three valid days (monitor worn for at least eight hours) of weekday data and one valid day of weekend data. If participants had more than this, all of the days of usable data were averaged. Periods of 20 minutes or more of continuous zeroes were considered nonwear times and not considered in the calculation of total wear time (Matthews, Ainsworth, Thompson, & Bassett, 2002). Counts were reintegrated to 60-s epochs, and cutpoints from Freedson, Melanson, and Sirard (1998) were used to categorize each minute of wear as sedentary, light, and moderate-to-vigorous physical activity. Minutes spent in each physical activity intensity level were divided by wear time in order to account for wear-time differences, providing an outcome variable with units of percentage of time spent in each intensity level.

Process Outcome Measures

The total number of game sessions scheduled was recorded. Game attendance was measured by the total number of times the participants came to the research site to play the game. The game log file also enabled us to calculate the total time the participants spent playing the game.

Game-Related Outcome Measures

The validated perceived need satisfaction of autonomy scale used in a previous study was employed (Peng et al., 2012). However, the 6-item scale revealed an extremely low reliability score at week 4 (Cronbach's alpha = .11), even though Cronbach's alpha was very high at week 1 (.92). Following Tavakol and Dennick (2011), the dataset was explored by deleting the least correlated item one at a time to see whether it improved the Cronbach's alpha result. Deleting the item "This game provided me with interesting options" improved the Cronbach's alpha from .11 to .19. Among the remaining five items, deleting the item "I had many opportunities to choose how to grow my character" improved the Cronbach's alpha from .18 to .32. Finally, among the remaining four items, deleting the item "I felt like I was free to decide for myself how to proceed in this game" improved the Cronbach's alpha from .32 to .56. Exploratory factor analysis also indicated that these three items loaded into one factor. Therefore, these three items were kept as the measure for perceived need satisfaction of autonomy: "I experienced a lot of freedom in the game," "I had a lot of choices in this game," and "I was able to play the game the way I wanted to play it." The resulting Cronbach's alpha was .88 and .56 at week 1 and week 4, respectively. However, the above attempt still did not result in a reliable measure of autonomy with Cronbach's alpha over .70. Therefore, we did not include the results of the effect on autonomy.

Perceived need satisfaction of competence was measured using a 5-item scale (Peng et al., 2012). Cronbach's alpha values were .79 and .74 at week 1 and week 4, respectively. The five items were "I felt competent at this game," "I felt a great sense of accomplishment playing this game," "I felt able to meet the challenge of performing well in this game," "I did not feel very capable when playing this game [reverse-code]," and "I felt that I was effective interacting in this game."

Perceived need satisfaction of relatedness was measured by adapting the relatedness subscale in PENS (Ryan et al., 2006) and the Basic Need Satisfaction At Work scale (Baard, Deci, & Ryan, 2004). The participants rated eight statements on a 7-point Likert scale anchored by 1 (*strongly disagree*) and 7 (*strongly agree*): "I felt a sense of camaraderie while playing this game," "I felt that the game characters supported me," "I really liked the characters I interacted with in this game," "I felt that the characters in the game cared about me," "When I was interacting with the characters in this game, I felt a lot of closeness," "When I was playing the game, I felt that the other game characters were with me together," "I felt that I formed relationships with other characters in this game," and "When I was playing the game, I felt that I was left alone all by myself." Cronbach's alpha values were .90 and .77 at week 1 and week 4.

The Physical Activity Enjoyment Scale (PACES) was adopted to measure the players' enjoyment of playing the different versions of the game at week 1 and week 4 (Kendzierski & Decarlo, 1991). Cronbach's alpha values were .88 and .69 at week 1 and week 4, respectively.

Future Play Motivation was measured based on Ryan et al. (2006). At week 1 and week 4 participants were asked to rate three statements on a 7-point scale anchored by 1 (*strongly disagree*) and 7 (*strongly agree*): "Given the chance I would play this game in my free time," "I would like to spend more time playing this game," and "I would like to continue playing this game." Cronbach's alpha values were .91 and .93 at week 1 and week 4, respectively. One item was employed to ask the participants from 1 (*extremely unlikely*) to 7 (*extremely likely*) how likely they would be to recommend this game to others at week 1 and week 4.

Statistical Analysis

Data analyses of the primary outcomes (percent time spent in sedentary, light, and MVPA) were only conducted among the participants who were equipped with the accelerometers. Data analyses of the game related outcomes and process outcomes were conducted among all the participants in the three game play groups. Missing data were not imputed, and completer analyses were conducted for the primary outcomes and the secondary outcomes. As the PA data were not normally distributed, square-root transformation was performed to satisfy the assumption of the statistical analysis because the transformation would not materially change statistical difference for accelerometry PA outcomes. The means and standard deviations of the PA data were still reported in the original form for easy interpretation. Baseline self-reported weekly MVPA minutes, walking minutes, BMI, and monthly gaming time were compared between those equipped with accelerometers and those without. No statistically significant differences were found. Additionally, these same variables were compared between those who remained in the study and those who dropped out. No statistically significant differences were found.

A mixed model analysis of covariance (ANCOVA) with intervention condition as the between-subjects factor and time (week 1 and week 5) as the within-subjects factor was conducted to examined whether the four groups differed in terms of the primary outcome measures (percent of time spent in sedentary, light, moderate, and vigorous physical activity) over time, controlling for baseline PA measures and seasonal effects due to two waves of data collection. When an interaction effect was found, simple ANCOVA at each level of the within-subjects factor was conducted, that is, separate ANCOVAs for week 1 (during intervention) and week 5 (immediately after intervention). The magnitude of the overall effect was explained through a magnitude of the partial eta square for the F statistic, where .01 .09, and .25 represent small, medium, and large effects, respectively.

A mixed model analysis of variance (ANOVA) examined the difference among the three game play groups in terms of the game related measures at week 1 and week 4. The model contained time (a within-subjects factor: week 1 and week 4) and group (a between-subjects factor: SDT-features-off AVG, SDT-features-on AVG, and SDT-features-on passive game). Separate models were used for each dependent variable. A significant main effect of group difference was the primary test. One-way ANOVA was used to examine group differences regarding process outcomes— game session scheduling, game attendance, and time spent playing the games. For all the ANOVA tests, Welch's ANOVA was used if the homogeneity assumption was violated.

Results

Primary Outcomes

Table 2 summarizes the means and standard deviations of the primary and process outcomes. Three mixed model ANCOVAs were conducted for sedentary activity, light PA, and MVPA and the results are summarized in Table 3. No main effect of intervention condition or main effect of time were found for sedentary activity, light PA, and MVPA. No interaction effects were found for sedentary activity and light PA. The only statistically significant difference revealed was the interaction effect for MVPA, $F(3, 84) = 2.89$, $p = .04$, $\eta^2 = .09$, indicating that the MVPA differences among the intervention conditions were dependent on time. To interpret the interaction effect, separate ANCOVAs at each level of the within-subjects factor—week 1 and week 5 were conducted, controlling for week 0 MVPA and seasonal effects. For week 1 MVPA, the four conditions did not differ, $F(3, 84) = .65$, $p = .58$. Neither wave of data collection, $F(1, 84) = 3.21$, $p = .077$, nor week 0 MVPA, $F(1, 84) = 1.58$, $p = .21$, were significant covariates. However, for week 5 MVPA, statistically significant difference was found, $F(3, 84) = 3.76$, $p = .014$, $\eta^2 = .12$. Wave of data collection was a significant covariate, $F(1, 84) = 12.99$, $p = .001$, $\eta^2 = .13$, but week 0 MVPA was not, $F(1, 84) = 2.94$, $p = .09$. Post hoc pairwise comparisons with Bonferroni correction indicated that SDT-features-on AVG condition had

Table 2
Means and Standard Deviations of Primary Outcomes and Process Outcomes

DV	SDT off AVG $n = 23$			SDT on AVG $n = 25$			SDT on passive game $n = 19$			Control $n = 23$		
	Week 0	Week 1	Week 5	Week 0	Week 1	Week 5	Week 0	Week 1	Week 5	Week 0	Week 1	Week 5
% time spent in sedentary activities	72.03 (8.19)	68.42 (8.00)	71.10 (7.63)	71.94 (8.33)	69.21 (9.14)	71.68 (7.45)	71.28 (9.43)	71.12 (7.04)	72.02 (4.47)	72.31 (9.58)	71.22 (9.03)	74.56 (8.77)
% time spent in light PA	21.39 (8.10)	25.31 (8.93)	22.56 (7.40)	22.83 (8.15)	25.73 (10.20)	18.89 (11.10)	22.03 (10.17)	21.91 (9.86)	19.69 (7.44)	18.34 (10.79)	22.68 (8.39)	19.50 (8.72)
% time spent in MVPA	6.58 (3.94)	6.26 (3.51)	6.35 (3.40)	5.23 (3.23)	5.06 (2.54)	9.43 (5.81)	6.69 (4.76)	6.97 (4.20)	8.29 (5.19)	9.36 (5.37)	6.10 (4.46)	5.93 (4.44)
Game session scheduling		9.33 (2.92)			10.17 (2.78)			10.73 (1.96)				
Game attendance		8.94 (3.14)			10.39 (2.30)			10.79 (1.93)				
Time spent in game		184.45 (68.91)			241.65 (89.38)			239.41 (70.47)				

Note. Only included those who had accelerometers and provided valid data at all these three weeks. SDT = self-determination theory; AVG = active video game. Standard deviations reported in parentheses.

Table 3
F Test Statistics From Mixed Model ANCOVAs for Sedentary Activity, Light PA, and MVPA

Activity	Time			Group			Time × Group			Covariate: Week 0 MVPA			Covariate: Wave of data collection		
	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2
Sedentary activity	.41	.008	.008	1.26	.29	.043	.30	.82	.011	22.16	.00	.21	.17	.68	.002
Light PA	.001	.98	.00	.80	.50	.028	1.16	.33	.04	6.63	.012	.073	1.83	.18	.021
MVPA	.85	.36	.01	1.87	.14	.063	2.89	.04	.094	3.70	.058	.042	12.29	.001	.13

greater MVPA than the control group at week 5, $p = .012$. There were no other statistical differences in MVPA between any other two groups. A cautionary note needs to be pointed out that the homogeneity assumption was violated in the mixed model ANCOVA for light PA at week 5. Levene's test of equality of error variance was statistically significant, $p = .01$, even after square-root transformation was applied for the light PA data.

Because data collection was conducted in two waves, potential seasonal effects were also explored. A mixed model ANOVA was conducted to see whether secondary activities, light PA, and MVPA differ among the two waves. A between-subjects main effect would indicate seasonal effect, which was in fact demonstrated by our data. Participants in the second wave (March-May) had greater MVPA than the first wave (January to March), $F(1, 88) = 8.94$, $p = .004$, $\eta^2 = .092$, which shows weather as an important factor impacting MVPA.

Process Outcomes

Means and standard deviations for compliance of game session scheduling, actual game attendance, and time spent in gaming were reported in Table 2. No statistically significant difference was found for compliance of game session scheduling, $F(2, 90) = 2.32$, $p = .11$. Significant group differences were found for game attendance, $F(2, 57.89) = 4.09$, $p = .022$, and total time in game, $F(2, 86) = 5.06$, $p = .008$. Post hoc pairwise comparison with Bonferroni correction indicated that players in the SDT-features-on AVG condition came to play the game more often than players in SDT-features-off AVG condition ($p = .016$). Players in SDT-features-on conditions, either played passively ($p = .015$) or actively ($p = .024$), spent more time playing the game than players in the SDT-features-off AVG condition.

Game-Related Outcomes

Table 4 summarizes the mixed model ANOVAs for the game related outcomes. A main effect of group difference was found for perceived need satisfaction of relatedness, $F(2, 84) = 3.93$, $p = .023$, $\eta^2 = .086$. Post hoc pairwise comparison with Bonferroni correction showed that the SDT-features-on AVG condition had greater perceived relatedness than the SDT-features-off AVG condition. No main effect of group difference was found for perceived need satisfaction of competence, $F(2, 84) = 1.66$, $p = .196$, $\eta^2 = .038$. Significant time effects were also found for perceived competence, $F(1, 84) = 81.53$, $p < .001$, $\eta^2 = .49$, and perceived relatedness, $F(1, 84) = 5.25$, $p = .025$, $\eta^2 = .059$. Specifically, over time, participants had increased perception of relatedness but decreased perception of competence. No group by time interaction effect was found.

The mixed model ANOVA did not reveal statistically significant group difference for game enjoyment, $F(2, 88) = 2.55$, $p = .084$, $\eta^2 = .055$. No significant group difference was found with regard to future play motivation, $F(2, 84) = 1.16$, $p = .317$, $\eta^2 = .027$. Significant group difference was found for likelihood of game recommendation, $F(2, 84) = 7.02$, $p = .002$, $\eta^2 = .143$. Post hoc pairwise comparison with Bonferroni correction indicated that players were more likely to recommend the SDT-features-on AVG than the SDT-features-on passive game ($p = .001$), but there was no difference of likelihood of recommendation between the SDT-features-on and SDT-features-off AVG groups. Significant time effects were also found for game enjoyment and future play motivation. Over time, the participants had decreased game enjoyment, $F(1, 88) = 42.40$, $p = .00$, $\eta^2 = .325$, and future play motivation, $F(1, 84) = 12.21$, $p < .001$, $\eta^2 = .127$. No time by

Table 4
Means, Standard Deviations, and F Test Statistics From Mixed-Model ANOVA for Game-Related Outcomes

Outcome	SDT off AVG		SDT on AVG		SDT on passive game		Time			Group			Time × Group		
	W1	W4	W1	W4	W1	W4	F	p	η^2	F	p	η^2	F	p	η^2
Autonomy	2.62 (1.12)	3.15 (1.00)	3.70 (1.62)	3.36 (1.03)	3.55 (1.10)	3.62 (.94)	.47	.49	.006	4.27	.017	.092	3.90	.024	.085
Competence	5.29 (.89)	4.09 (1.24)	5.28 (1.01)	4.08 (1.06)	4.91 (1.11)	3.76 (.86)	81.52	.00	.49	1.66	.20	.038	.02	.98	.00
Relatedness	3.14 (1.24)	3.33 (.88)	3.81 (1.34)	4.00 (1.11)	3.53 (1.19)	3.99 (.75)	5.25	.025	.059	3.93	.023	.086	.52	.60	.012
Game enjoyment	4.63 (.74)	4.23 (.80)	4.80 (.75)	4.28 (.63)	4.40 (.86)	3.96 (.51)	42.40	.00	.325	2.55	.084	.055	.29	.75	.007
Future play motivation	4.71 (1.62)	4.14 (1.76)	4.84 (1.23)	4.12 (1.58)	4.25 (1.54)	3.75 (1.40)	12.21	.001	.127	1.16	.32	.027	.15	.86	.004
Game recommendation	4.30 (1.81)	4.21 (1.66)	5.03 (1.54)	4.74 (1.69)	3.68 (1.59)	3.89 (1.50)	.048	.83	.001	7.02	.002	.143	.34	.71	.008

Note. Effect sizes (partial eta square: η^2): small effect = .01, medium effect = .09, large effect = .25. W1 = week 1; W4 = week 4. Standard deviations reported in parentheses.

group interaction was found for game enjoyment, future motivation, and game recommendation.

Discussion

This study examined whether an AVG with SDT-supported features would be more effective in reducing sedentary behaviors and increasing physical activity (light, moderate, and vigorous) among players during the time that they have access to the AVG and immediately after such AVG intervention is over, compared with an AVG without such need satisfaction features, as well as the control group and the passive game play group. Additionally, this study investigated whether an AVG with SDT supported features would result in greater game engagement manifested by attendance, time spent on game, game enjoyment, future game play motivation, and likelihood of recommendation of game, as well as greater needs satisfaction of autonomy, competence, and relatedness in comparison to an AVG without those SDT supported features.

It was found that playing the self-determination theory–supported AVG resulted in greater MVPA compared with the control group immediately postintervention, although no statistically significant difference was found between the theory-supported AVG and the AVG without the additional theory-supported features or the theory-supported AVG and a passive game with theory-supported features. A possible explanation for the difference in MVPA between the theory-supported AVG and the control group immediately after intervention would be that through the four weeks of intervention of playing the AVG, the insufficiently active young adults started to become more active. After the intervention was over, the SDT-features-on AVG may have motivated participants to engage in some real life physical activities, which resulted in significantly greater MVPA compared with the control group, although there is no evidence to support this actually occurred except the increased MVPA minutes. This is consistent with the proposition that a theory-based AVG might serve as a gateway to introduce sedentary or insufficiently active individuals to fun physical activities which will ultimately stimulate them to become more active in real life (Lieberman et al., 2011).

What was perplexing was that the first week did not result in statistically significant change of physical activity, including light PA which was supposed to be the range of PA the game elicited in the first week. One possible explanation was that the effect size might be too small and our sample was not well-powered. Another possible explanation was that participants needed to come to the research site to play the game and most of them came by walking, which might dilute the effect of AVG.

Nevertheless, we consider the most important findings supporting the importance of theory-guided intervention design are the process outcomes and the game related outcomes. Game attendance and game time are two variables that not only provide empirical evidence for intervention fidelity but also evidence that theory-supported game features impact objectively measured motivation. Participants in the SDT-features-on AVG condition came to the intervention site more to play the game and spent more time playing the game than the SDT-features-off AVG condition.

The SDT-supported features also impacted players' need satisfaction of autonomy and need satisfaction of relatedness as expected from lab study results (Peng et al., 2012). This finding suggests that to continuously engage participants to come back to play a video game, in particular an AVG, it is important to have need satisfaction supportive game features. Previous AVG intervention showed high burn-out rate or significantly diminished AVG use after the initial weeks (e.g., Maloney et al., 2008). The AVGs used in the previous interventions were first generation commercial off-the-shelf ones and were not designed for physical activity promotion or integrated with theory support for prolonged motivation and engagement. Our findings that playing AVGs with the theory-based features resulted in greater attendance and psychological need satisfaction further warrant the importance of theory guiding in intervention development (Baranowski, Anderson, & Carmack, 1998; Brug, Oenema, & Ferreira, 2005).

No statistically significant difference of need satisfaction of competence was found. One possible explanation might be that the game engine (Unity) used to develop the game went through some backend platform change during the intervention period. This change resulted in an error in the game world. Because this was an error in the third-party game engine, there was nothing that our game developer could do to fix it and this error prevented all players from successfully completing a level, regardless of their study conditions. This inability to proceed in the game might have negatively influenced every player's need satisfaction of competence and washed out the effects of the SDT features such as dynamic difficult adjustment, heroism meter, and achievement badges.

Additionally, because no significant group differences were found for game enjoyment and future play motivation, the lack of difference in need satisfaction of competence might also contribute to that as need satisfaction contributes to enjoyment and future play motivation (Ryan et al., 2006). The players were found to be more likely to recommend the game to others when they played the SDT-features-on versions actively than passively, suggesting that active video games were positively received and accepted by insufficiently active young adults, which is consistent with previous findings (Lyons et al., 2011).

Significant time effects were found for a number of the game related outcomes. Over time, the players' need satisfaction of competence, game enjoyment, and future play motivation decreased. Although no decreased adherence were found over time, this might be an issue over longer period of time, as identified in previous studies (Madsen, Yen, Wlasiuk, Newman, & Lustig, 2007). The other time effect of the game related outcomes was the increase of need satisfaction of relatedness over time. The game features were not manipulated optimally to support need satisfaction of relatedness, as only nonplay characters were used, either through voice-over, or supportive conversations, and multiplayer features were not employed. However, our data suggest that even if the participants did not play with other players, only interacting with the virtual nonplayer characters over the period of four weeks contributed to need satisfaction of relatedness. This finding was consistent with the media equation theory or the computers as social actors framework such that people are prone to perceive socialness from small anthropomorphic cues in computer generated interfaces or systems and behave according to social rules and be impacted by the socialness of these computer generated interfaces and systems (Reeves & Nass, 1996). However, although need satisfaction of relatedness generated by the nonplayer characters increased over time, this need satisfaction did not translate into game enjoyment or future play motivation as indicated in the multiple regression results. This implies that need satisfaction of relatedness generated by other players may be necessary, suggesting that multiplayer gaming either in face-to-face or networked modality may need to be included to contribute to game enjoyment and future game play motivation.

The strengths of the current research were the experimental design with random assignment of participants to groups; the use of a theory-guided AVG (not off-the-shelf commercial games) designed for a specific target audience (insufficiently active young adults who play video games); and the use of objective monitors of PA (accelerometers) over week-long intervals at 3 times in the design.

The current research also has a number of limitations. First, the duration of the intervention was rather short. Second, the technical difficulty attributable to the game engine issue may have unexpectedly influenced the need satisfaction of competence. Third, although need satisfaction difference was found among the SDT-on versus SDT-off condition, this did not further lead to game enjoyment or future play motivation difference. Fourth, the sample size was rather small and the pilot trial was not adequately powered. Fifth, physical activities were only objectively measured at baseline, week 1, and immediately after intervention (week 5). The lack of assessment of PA beyond the first week during the intervention limited us in examining how PA change over time during the intervention and how the AVG impacted PA over time. Sixth, the Cronbach's alpha of the measure of need satisfaction of autonomy was very poor despite the data-driven attempt to improve reliability, limiting our ability to interpret and discuss the results regarding need satisfaction of autonomy. Seventh, an incentive up to \$100 may affect the generalizability of the study, although the incentive was only provided for outcome data collection and not for game attendance. Eighth, our sample was self-selected college students, limiting the generalizability of the findings. Finally, as the current research required customized dancepad to play the game on a Mac computer, the intervention could not have been implemented and generalized in a more natural, home-based setting.

In conclusion, the current research provides some evidence that playing a SDT-based AVG resulted in greater of MVPA compared to the control group immediately after the intervention was over. AVGs with the theory-supported features also resulted in greater adherence and psychological need satisfaction. The findings indicate that including AVG features guided with motivation theory may be a method of addressing common problems with adherence and increasing effectiveness of active gaming.

References

Baard, P. P., Deci, E. L., & Ryan, R. M. (2004). Intrinsic need satisfaction: A motivational basis of performance and well-being in two work settings. *Journal of Applied Social Psychology, 34,* 2045–2068. http://dx.doi.org/10.1111/j.1559-1816.2004.tb02690.x

Baranowski, T., Anderson, C., & Carmack, C. (1998). Mediating variable framework in physical activity interventions. How are we doing? How might we do better? *American Journal of Preventive Medicine, 15,* 266–297. http://dx.doi.org/10.1016/S0749-3797(98)00080-4

Barkley, J. E., & Penko, A. (2009). Physiologic responses, perceived exertion, and hedonics of playing a physical interactive video game relative to a sedentary alternative and treadmill walking in adults. *Journal of Exercise Physiology Online, 12,* 1389–1398.

Bell, S., & Lee, C. (2005). Emerging adulthood and patterns of physical activity among young Australian women. *International Journal of Behavioral Medicine, 12,* 227–235. http://dx.doi.org/10.1207/s15327558ijbm1204_3

Biddiss, E., & Irwin, J. (2010). Active video games to promote physical activity in children and youth: A systematic review. *Archives of Pediatrics & Adolescent Medicine, 164,* 664–672. http://dx.doi.org/10.1001/archpediatrics.2010.104

Brug, J., Oenema, A., & Ferreira, I. (2005). Theory, evidence and intervention mapping to improve behavior nutrition and physical activity interventions. *The International Journal of Behavioral Nutrition and Physical Activity, 2,* 2. http://dx.doi.org/10.1186/1479-5868-2-2

Centers for Disease Control and Prevention. (2011). *Behavioral risk factor surveillance system survey data*. Atlanta, GA: Author.

Colley, R. C., Hills, A. P., King, N. A., & Byrne, N. M. (2010). Exercise-induced energy expenditure: Implications for exercise prescription and obesity. *Patient Education and Counseling, 79,* 327–332. http://dx.doi.org/10.1016/j.pec.2010.03.001

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York, NY: Plenum Press. http://dx.doi.org/10.1007/978-1-4899-2271-7

Dishman, R. K., Motl, R. W., Saunders, R., Felton, G., Ward, D. S., Dowda, M., & Pate, R. R. (2005). Enjoyment mediates effects of a school-based physical-activity intervention. *Medicine and Science in Sports and Exercise, 37,* 478–487. http://dx.doi.org/10.1249/01.MSS.0000155391.62733.A7

Edmunds, J., Ntoumanis, N., & Duda, J. L. (2006). A test of self-determination theory in the exercise domain. *Journal of Applied Social Psychology, 36,* 2240–2265. http://dx.doi.org/10.1111/j.0021-9029.2006.00102.x

Epstein, L. H., Beecher, M. D., Graf, J. L., & Roemmich, J. N. (2007). Choice of interactive dance and bicycle games in overweight and non-overweight youth. *Annals of Behavioral Medicine, 33,* 124–131. http://dx.doi.org/10.1007/BF02879893

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. *Medicine and Science in Sports and Exercise, 30,* 777–781. http://dx.doi.org/10.1097/00005768-199805000-00021

Gagné, M., Ryan, R. M., & Bargmann, K. (2003). Autonomy support and need satisfaction in the motivation and well-being of gymnasts. *Journal of Applied Sport Psychology, 15,* 372–390. http://dx.doi.org/10.1080/714044203

Haskell, W. L., Lee, I.-M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., . . . Bauman, A., & the American College of Sports Medicine, & American Heart Association. (2007). Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation, 116,* 1081–1093. http://dx.doi.org/10.1161/CIRCULATIONAHA.107.185649

Kendzierski, D., & Decarlo, K. J. (1991). Physical Activity Enjoyment Scale: Two validation studies. *Journal of Sport & Exercise Psychology, 13,* 50–64.

Lenhart, A., Jones, S., & Macgill, A. R. (2008, December 7). Pew Internet Project data memo: Adults and video games. Retrieved June 22, 2011, from http://www.pewinternet.org/~/media//Files/Reports/2008/PIP_Adult_gaming_memo.pdf.pdf

Lieberman, D. A., Chamberlin, B., Medina, E., Jr., Franklin, B. A., Sanner, B. M., Vafiadis, D. K., & the Power of Play: Innovations in Getting Active Summit Planning Committee. (2011). The power of play: Innovations in Getting Active Summit 2011: A science panel proceedings report from the American Heart Association. *Circulation, 123,* 2507–2516. http://dx.doi.org/10.1161/CIR.0b013e318219661d

Lyons, E. J., & Hatkevich, C. (2013). Prevalence of behavior changing strategies in fitness video games: Theory-based content analysis. *Journal of Medical Internet Research, 15,* e81. http://dx.doi.org/10.2196/jmir.2403

Lyons, E. J., Tate, D. F., Ward, D. S., Bowling, J. M., Ribisl, K. M., & Kalyararaman, S. (2011). Energy expenditure and enjoyment during video game play: Differences by game type. *Medicine and Science in Sports and Exercise, 43,* 1987–1993.

Lyons, E. J., Tate, D. F., Ward, D. S., Ribisl, K. M., Bowling, J. M., & Kalyanaraman, S. (2014). Engagement, enjoyment, and energy expenditure during active video game play. *Health Psychology, 33,* 174–181. http://dx.doi.org/10.1037/a0031947

Madsen, K. A., Yen, S., Wlasiuk, L., Newman, T. B., & Lustig, R. (2007). Feasibility of a dance videogame to promote weight loss among overweight children and adolescents. *Archives of Pediatrics & Adolescent Medicine, 161,* 105–107. http://dx.doi.org/10.1001/archpedi.161.1.105-c

Maloney, A. E., Bethea, T. C., Kelsey, K. S., Marks, J. T., Paez, S., Rosenberg, A. M., . . . Sikich, L. (2008). A pilot of a video game (DDR) to promote physical activity and decrease sedentary screen time. *Obesity, 16,* 2074–2080. http://dx.doi.org/10.1038/oby.2008.295

Markland, D. (1999). Self-determination moderates the effects of perceived competence on intrinsic motivation in an exercise setting. *Journal of Sport & Exercise Psychology, 21,* 351–361.

Matthews, C. E., Ainsworth, B. E., Thompson, R. W., & Bassett, D. R., Jr. (2002). Sources of variance in daily physical activity levels as measured by an accelerometer. *Medicine and Science in Sports and Exercise, 34,* 1376–1381. http://dx.doi.org/10.1097/00005768-200208000-00021

Peng, W., Crouse, J. C., & Lin, J.-H. (2013). Using active video games for physical activity promotion: A systematic review of the current state of research. *Health Education & Behavior, 40,* 171–192. http://dx.doi.org/10.1177/1090198112444956

Peng, W., Lin, J.-H., & Crouse, J. (2011). Is playing exergames really exercising? A meta-analysis of energy expenditure in active video games. *Cyberpsychology, Behavior, and Social Networking, 14,* 681–688. http://dx.doi.org/10.1089/cyber.2010.0578

Peng, W., Lin, J.-H., Pfeiffer, K. A., & Winn, B. (2012). Need satisfaction supportive game features as motivational determinants: An experimental study of a self-determination theory guided exergame. *Media Psychology, 15,* 175–196. http://dx.doi.org/10.1080/15213269.2012.673850

Przybylski, A. K., Rigby, C. S., & Ryan, R. M. (2010). A motivational model of video game engagement. *Review of General Psychology, 14,* 154–166. http://dx.doi.org/10.1037/a0019440

Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, television, and new media like real people and places*. New York, NY: Cambridge University Press.

Ryan, R. M., & Deci, E. L. (2000a). The darker and brighter sides of human existence: Basic psychological needs as a unifying concept. *Psychological Inquiry, 11,* 319–338. http://dx.doi.org/10.1207/S15327965PLI1104_03

Ryan, R. M., & Deci, E. L. (2000b). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55,* 68–78. http://dx.doi.org/10.1037/0003-066X.55.1.68

Ryan, R. M., Rigby, C. S., & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion, 30,* 344–363. http://dx.doi.org/10.1007/s11031-006-9051-8

Salmon, J., Owen, N., Crawford, D., Bauman, A., & Sallis, J. F. (2003). Physical activity and sedentary behavior: A population-based study of barriers, enjoyment, and preference. *Health Psychology, 22,* 178–188. http://dx.doi.org/10.1037/0278-6133.22.2.178

Silva, M. N., Vieira, P. N., Coutinho, S. R., Minderico, C. S., Matos, M. G., Sardinha, L. B., & Teixeira, P. J. (2010). Using self-determination theory to promote physical activity and weight control: A randomized controlled trial in women. *Journal of Behavioral Medicine, 33,* 110–122. http://dx.doi.org/10.1007/s10865-009-9239-y

Staiano, A. E., Abraham, A. A., & Calvert, S. L. (2012). Motivating effects of cooperative exergame play for overweight and obese adolescents. *Journal of Diabetes Science and Technology, 6,* 812–819.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2,* 53–55. http://dx.doi.org/10.5116/ijme.4dfb.8dfd

Tremblay, M. S., Colley, R. C., Saunders, T. J., Healy, G. N., & Owen, N. (2010). Physiological and health implications of a sedentary lifestyle. *Applied Physiology, Nutrition, and Metabolism, 35,* 725–740. http://dx.doi.org/10.1139/H10-079

Appendix

Description of the Self-Determination Theory–Supported Game Features

Autonomy-Supportive Game Features

Three game features were manipulated to correspond to the concept of autonomy. First, character customization allowed players to personalize their characters in the game. In the autonomy supportive features on condition, players were offered options to choose the character's gender and change the character's appearance such as skin tone, hair color, eye color, etc. In the autonomy supportive features off condition, the players were just provided with a default character matching their biological sex and did not have the option to customize the appearance of the characters. Second, in the autonomy supportive features on condition, players could choose how to donate treasure to different Gods in the altar in exchange for different types of rewards, including increase of strength, speed, or damage power for character development. Each time the players made a choice in which area they want to develop their characters, the internal game system would track the statistics and this would influence how much damage the their game characters could endure from the opponents (strength), how fast the their game characters could navigate (speed), and how much damage their game characters could cast on their opponents (damage power). What skills the players chose to improve would be critical, as this provided "skill boost" to their future game play and future character performance would largely depends on this. In the autonomy supportive features off condition, players did not have the choice over donations for character growth. When they found a treasure and picked it up, the game just automatically donated the treasure to increase speed, strength, and damage power in a sequential way. Third, players could also choose from a range of different answers when conversing with other non-player characters in the game if they were in the autonomy supportive game features on condition. Otherwise, there was only one option in the dialog and thus giving no choice for the player.

Competence-Supportive Game Features

Based on SDT and current literature, three features were designed in this game to support the need satisfaction of competence. First, in the competence supportive features on condition, a dynamic difficulty mechanism would adjust along with players' performance in the game. For example, after a player successfully completed a challenge, he or she would be given a more difficult challenge. Conversely, if a player was struggling, then the subsequent challenges would be easier. In competence supportive features off condition, there would be no dynamic difficulty mechanism. Therefore, the difficulty level would remain the same, regardless of the players' performance. Second, a heroism meter was shown on the screen to reflect how well a player handled the game and its challenges. Players would receive heroism points when performing well in the game. Conversely, players in the competence supportive features off condition would not be able to see the heroism meter. Third, the game also created various types of achievement badges for players. Players could earn and browse their achievements in the achievement menu of the game. Players in the competence supportive features off condition were not able to earn achievements throughout the game.

Relatedness-Supportive Game Features

Because of the limitation of the single-player role-playing game, our design could not provide real-world social connections with other players. Although the relatedness features in this video game were not manipulated optimally, two features were designed to reflect the concept of relatedness. First, the presence of voice-over in the video game created an environment for players to perceive social presence. Second, the presence of supportive dialog was another feature to increase players' perceived social support and connections to the non-player characters in the game.

Received August 28, 2014
Revision received May 30, 2015
Accepted September 4, 2015 ■