Story Immersion May Be Effective in Promoting Diet and Physical Activity in Chinese Children

Jing Jing Wang, PhD[1]; Tom Baranowski, PhD[2]; Patrick W. C. Lau, PhD[1]; Richard Buday, FAIA[3]; Yang Gao, PhD[1]

ABSTRACT

Objective: To evaluate the effect of playing a health video game embedded with story immersion, Escape from Diab (Diab), on children's diet and physical activity (PA) and to explore whether children immersed in Diab had greater positive outcomes.

Design: Two groups, nonrandomized; 3 outcome assessments: at baseline, immediately after the game (post 1), and 8–10 weeks after the game (post 2).

Participants: A total of 179 Chinese children aged 8–12 years.

Intervention: The treatment group played Diab; the control group received no intervention.

Main Outcome Measures: Motivation; self-efficacy; preference for fruit, vegetables, water, and PA; as well as PA behavior.

Analysis: Adjusted changes to post 1 and post 2 by ANCOVA controlling for demographic and baseline variables.

Results: Children who played Diab had increased intrinsic motivation for fruit and water, self-efficacy for PA, and self-reported PA scores at post 1 (all $P < .05$). Children with higher immersion scores (above the median) had increased intrinsic motivation for fruit and water, and autonomous and controlled motivation for PA at post 1 (all $P < .05$). However, these were not significant at post 2.

Conclusions and Implications: Diab provides a promising innovative medium for promoting Chinese children's psychological correlates of diet and PA and PA behavior. However, its maintenance of effectiveness needs to be enhanced and mechanisms of change need to be investigated more thoroughly.

Key Words: video game, story immersion, fruit, vegetable, water, child, self-efficacy, obesity, diabetes (*J Nutr Educ Behav*. 2017;49:321-329.)

Accepted January 2, 2017.

INTRODUCTION

Obesity tracks from childhood into adulthood,[1] which shortens the life span, impairs functional ability, and diminishes quality of life.[2] Innovative technologies may provide alternative methods to encourage healthy behaviors for childhood obesity prevention.[3] Recently, with the growing interest in video games not only as entertainment but also an educational medium,[4] a steadily increasing number of video games have been developed for serious purposes, called serious games, which are characterized by both their quality of fun (ie, components that entertain players through animation, storyline, and sound effects) and their seriousness (ie, components that promote behavior modification through tailoring, problem solving, and goal setting). Games for Health (G4H), a type of serious game, were designed to encourage players to modify their health-related attitudes and behaviors.[5] The G4Hs are interactive and could influence players' cognitions and affect, generate positive emotions, and effect health behaviors.[6]

A narrative is defined as "the framework for the sequence of events that make up the plot we see, and the story we imagine."[7] Narrative is considered to be a basic game feature that could universally attract players and create playing enjoyment.[8] Immersion in the story can be described as a state of mental absorption in which the player is consumed by the narrative.[8,9] Story immersion refers to the process that a player experiences from active engagement with the narrative. A G4H embedded with

[1]Department of Physical Education, Faculty of Social Sciences, Hong Kong Baptist University, Hong Kong, China

[2]Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, TX

[3]Archimage, Houston, TX

Conflict of Interest Disclosure: The authors' conflict of interest disclosures can be found online with this article on www.jneb.org.

Address for correspondence: Patrick W.C. Lau, PhD, Department of Physical Education, Academic and Administration Bldg, 15 Hong Kong Baptist University Rd, Kowloon Tong, Hong Kong, China; Phone: (852) 3411 5634; Fax: (852) 3411 5757; E-mail: wclau@hkbu.edu.hk

http://dx.doi.org/10.1016/j.jneb.2017.01.001

well-crafted narratives may offer an especially suitable alternative for behavior modification, because players may experience psychological absorption while being fully immersed in games. The immersion could draw their close attention to the provided game context and behavior change components, and subsequently engender a greater health outcome.[10]

Escape from Diab (Diab) (Archimage, Inc, Houston, TX) is a G4H designed with story immersion to lower the risk of obesity and type 2 diabetes by changing attitudes and behaviors related to diet and physical activity (PA). In American children, positive changes in psychological correlates were observed in a 1-arm trial[11]; improvements in behavioral indicators of diet and PA were observed in another study.[12] An individual interview study confirmed the acceptability and applicability of Diab among Hong Kong Chinese children[13]; however, no study comprehensively explored its intervention effect on both psychological correlates of diet and PA and PA behavior in Chinese children.

Thus, the current study conducted the intervention using Diab and examined its effect on improving the psychological and behavioral indicators of diet and PA in Chinese children. The authors hypothesized that (1) playing Diab would improve Chinese children's self-efficacy, motivation, and preferences for diet and PA; and (2) story immersion in Diab would induce a more beneficial effect.

METHODS

Study Design

This study was a nonrandomized trial. Participants in the intervention group played Diab in the school setting. The control group received no intervention. Outcome assessments were conducted at baseline, immediately after the game (post 1: about 8–10 weeks after baseline), and 8–10 weeks after the game (post 2: 8–10 weeks after completion of game playing; follow-up times were kept the same as the duration of intervention for each participating school). Written informed consent was obtained from each participant and parents or guardians. The study was approved by the Committee on the Use of Human and Animal Subjects in Teaching and Research at Hong Kong Baptist University and was registered with the Centre for Clinical Research and Biostatistics.

Participants

At a significance level of $P < .05$, a power of 80%, and a constant correlation of 0.3 for 3 repeated measures, and taking a 20% dropout rate into account, 176 participants (2 groups, n = 88/group) were required to detect a small to moderate overall effect (Cohen's $d = 0.25$).[14] Students with physical diseases and psychological illnesses that may have prevented their participating in PA and eating a normal diet were excluded. A total of 179 students aged 8–12 years (mean, 10.2 years; 103 males) from 4 primary schools with English as the medium of instruction were included. Four schools had a similar size and were located in different Hong Kong districts that varied in student socioeconomic status (SES) (1 from high SES, 1 from medium SES, and 2 from low SES according to local statistics).[15] Participants in the same school were allocated into either the intervention or the control group to minimize potential moderating effects of SES.

Intervention: G4H: Diab

Diab was designed based on social cognitive[16] (eg, functional knowledge on how to select appropriate portion sizes, self-efficacy to eat fruit for breakfast), self-determination[17] (eg, autonomy to choose 20 kinds of healthy foods independently, competence to perform PA successfully), and elaboration-likelihood models[18] (eg, identifying the problem in setting goals for vegetable intake, and finding the solutions).[5] Using 3-dimensional scenes and animated characters, Diab tells the story of DeeJay, an athletic and healthy modern-day youth. He accidentally falls through the floor of an abandoned building into a world, Diab, where fruit, vegetables, and PA are forbidden by evil King Etes. DeeJay is befriended by a group of youth who begin to plot their escape from Diab by adopting a healthier lifestyle under DeeJay's guidance. The video game was composed of 9 episodes. Within each episode were 3–4 action-adventure mini-games. The session-by-session mini-games in each episode were described elsewhere.[12] Behavior change components, mini-games with tailored knowledge, motivational statements, goal setting and review, feedback, problem solving, and behavioral inoculation, were integrated into Diab.[5] Children were required to set goals at the end of each episode (diet goals in episodes 1–4 and PA goals in episodes 5–8). Goal setting in the game included action goals (ie, select specific foods and number of days to attempt goals) and coping goals (ie, identify the most likely barrier to achieving the goal and choose an effective solution for overcoming the barrier).

Procedure

Participants who had schedule conflicts with play sessions were assigned to the control group. The remaining participants who were available for the playing schedule were randomly assigned into the intervention or control groups. Participants in the intervention group (n = 95) were arranged to play Diab in the school's multimedia classroom on single consoles at the scheduled sessions (play session: 2 40-minute morning sessions before classes in 2 schools or 1 90-minute afternoon session after school in the other 2 schools). During each session, participants were asked to play 1 episode. Players could return to the current or previous episode and replay the mini-games if they had time remaining in the session but could not move to the following episode until the next game session. A translation of food and PA vocabulary was provided on the multimedia screen during play. Children in the control group (n = 84) received no intervention. The intervention lasted 8-10 weeks depending on the completion of game play. During the session, 1–2 researchers were present to monitor children's progress and provide assistance regarding possible hardware or software problems. After playing, a game controller worth $50 HK and a game CD were offered to participants in the treatment group as incentives. The no-treatment concurrent control was set. Children in the control group adopted the general diet and PA information and behaviors as usual during the program. After completing the final test at post 2, a game controller and Diab game CD with activation code were provided to participants in the control group to encourage them to play Diab by themselves at home.

Measures

The translation of questionnaires used in this study followed a standard procedure with translation and back translation by 3 bilingual speakers (ie, English and Cantonese). Five primary students were invited to an individual interview to test the questionnaires; minor revisions to wording were made according to their feedback.

Demographics. Children's height and weight were measured and body mass index (BMI) was calculated at baseline.

Immersion. Immersion was assessed immediately after all Diab episodes were played, using an 18-item immersion scale adapted from the narrative transportation scale to be specific to Diab (Cronbach $\alpha = .91$).[19] Participants were required to rate their levels of agreement with statements (eg, At least 1 of the Diab characters reminds me of myself) (1 = do not agree; 2 = somewhat agree; 3 = agree a lot; score range, 18–54).

Intrinsic motivation for fruit, vegetables, and water. Intrinsic motivation for fruit, vegetables, and water (FVW) was assessed with 12 items for fruit ($\alpha = .73$), 9 for vegetables ($\alpha = .72$), and 9 for water ($\alpha = .73$).[11] Children indicated whether why the reason they ate or drank the item originated from their inherent satisfaction: for example, I usually drink water because drinking water makes me happy (1 = I am not sure; 2 = I am a little bit sure; 3 = I am very sure).

Physical activity motivation. Physical activity motivation was assessed with a validated 16-item scale[20] with 3 items for intrinsic motivation (ie, inherent satisfaction in doing the behaviors), 5 for identified regulation (ie, recognizing the value of the behavior and accepting the regulatory process), 3 for introjected regulation (ie, involving internalized rules or demands), and 5 for external regulation (ie, from external locus of initiation of behaviors: for example, for avoiding punishment or gaining reward). Each item used a 7-point Likert scale (eg, 1 = not at all true; 4 = somewhat true; 7 = very true). A sample item was: I am regularly active because I enjoy being active. A score for autonomous motivation ($\alpha = .88$) was created by summing the items in the intrinsic motivation and identified regulation subscales indicating a sense of personal volition that originates from an internal perceived locus of causality for the behavior; introjected and external regulations items were summed to form a controlled motivation score that originated from an external perceived locus of causality ($\alpha = .79$).

Self-efficacy for FVW. Self-efficacy for FVW was assessed using validated 12-item ($\alpha = .86$), 8-item ($\alpha = .85$), and 5-item scales ($\alpha = .79$).[21] Each item asked about FVW intake behavior (eg, How sure are you that you can eat 1 portion of fruit or vegetables for a snack at home at least 4 d/w?) (1 = I am not sure; 2 = I am a little bit sure; 3 = I am very sure).

Physical activity self-efficacy. Physical activity self-efficacy was assessed using a 12-item scale ($\alpha = .91$).[22] A sample item was: How sure are you that you can be physically active >30 minutes for 1 day, even when you have lots of homework? (1 = I am not sure; 2 = I am a little bit sure; 3 = I am very sure).

Fruit, vegetables, and water preferences. Fruit, vegetable, and water preferences were measured using a validated 37-item scale ($\alpha = .90$).[23] Items asked how much children liked different types of food (eg, plums, oranges) (1 = I have never tasted it; 2 = I do not like it; 3 = I like it a little; and 4 = I like it a lot).

Physical activity preference. Physical activity preference was assessed using a validated 28-item scale ($\alpha = .84$).[24] In a way similar to the FVW preference scale, each item asked about a form of PA (eg, bicycling, swimming).

Self-reported PA. The researchers used the Physical Activity Questionnaire for Older Children (PAQ-C)[25] to measure self-reported PA ($\alpha = .79$). The PAQ-C items were used to compute moderate to vigorous PA for the day as a whole and for segments during the day using a 5-point Likert scale (eg, 1 = none; 3 = 2–3 days; 5 = 5 days for the evening or weekend).

Objective PA. The ActiGraph GT3X (ActiGraph, Pensacola, FL)[26] was used to measure objective PA. Children were asked to wear the ActiGraph for 7 consecutive days. Cutoff points developed by Evenson et al[27] were used to determine the levels of PA intensity (sedentary, ≤100 counts/min; light PA, >100 counts/min; moderate to vigorous PA, ≥2,296 counts/min). Of the 179 participants, 82.1% provided ≥3 valid days of accelerometer data (including 1 weekend day) at baseline and 60.3% at post 1. Because of conflicts of time and resources for schools, objective PA assessment was not conducted at post 2.

Social desirability. Social desirability (SocD) describes a type of response bias and reflects the desire to give answers that meet the expectations of others, but not the true response. Social desirability is the tendency to overestimate desirable behaviors and underestimate undesirable ones.[28] To control for this type of bias, SocD was measured by a 9-item Lie Scale from the revised children's Manifest Anxiety Scale[29] ($\alpha = .87$) and was adjusted in the analysis.

Statistical Analyses

Baseline characteristics and measures for the treatment and control groups were compared using Pearson's chi-square test of homogeneity for categorical variables and independent *t* test for continuous variables (2-sided $P < .05$) in SPSS 20.0 (IBM Corporation, Armonk, NY). Participants in the treatment group were divided into high and low immersion subgroups according to whether their immersion scores were above or below the median scores (36.0). For the treatment vs control groups and high vs low immersion groups, the authors examined changes to post 1 and post 2 (minus baseline) using ANCOVA, controlling for age, gender, BMI, SocD, and baseline variables. Adjusted means and 95% confidence intervals (CIs) were reported as effect sizes. To examine further the contribution of immersion to the treatment effect, partial correlations controlling for age, gender, and BMI were performed between the immersion scale and change scores. According to the principle of intention to treat, similar analyses were performed in all participants as well. Information for children who did not provide complete data was imputed using the last observation carried forward method.

RESULTS

Of 179 participants, 166 (92.7%) provided completed data at post 1 and 163 did so at post 2 (91.1%). The retention rate was 92.6% in the treatment group and 89.3% in the control group (Figure). There were no significant differences in gender and BMI between the treatment and control groups. Compared with the control group, the treatment group had more children aged 11–12 years ($\chi^2[1] = 5.60$; $P = .09$) (Table 1). No differences existed in demographics or anthropometrics between those retained and eliminated from the sample.

Measures were normally distributed and no suspicious outliers were detected. Table 2 presents the results for all measures stratified by group using ANCOVAs at each time point. At post 1, there were significant adjusted changes (95% CI) between the treatment and control groups in intrinsic motivation for fruit: 1.6 (0.1–3.1), intrinsic motivation for water: 1.2 (0.2–2.3), self-efficacy for PA: 2.4 (0.5–4.4), and PAQ-C: 1.9 (0.3–3.4), which all increased in the treatment group but decreased in the control group. However, these significant adjusted changes were not detected at post 2.

Upon completing all Diab episodes, 88 children in the treatment group reported a complete immersion score using the 18-item scale. The immersion score ranged from 20.0 to 52.0 with an average value of 37.8 (SD, 9.2), close to the center score of 36.0. Partial correlation between the immersion scale with change score was significant for autonomous motivation for PA at post 1 ($r = .27$; $P = .04$) but not in changes of other measures at either time point (all $P > .05$). Table 3 presents high and low immersion-level means for the treatment group children at 3 time points. At post 1, there were significant adjusted changes (95% CI) between the 2 groups in intrinsic motivation for fruit: 2.2 (0.3–4.2), water: 2.2 (0.7–3.7), autonomous motivation for PA: 3.9 (0.3–8.1), and controlled motivation for PA: 4.6 (0.3–8.9), which all increased in the high immersion group but decreased in the low immersion group. However, these significant adjusted changes were not detected at post 2.

Results regarding the outcomes with imputed data using the last observation carried forward method were in line with those reported previously among the participants who provided complete data (data not shown).

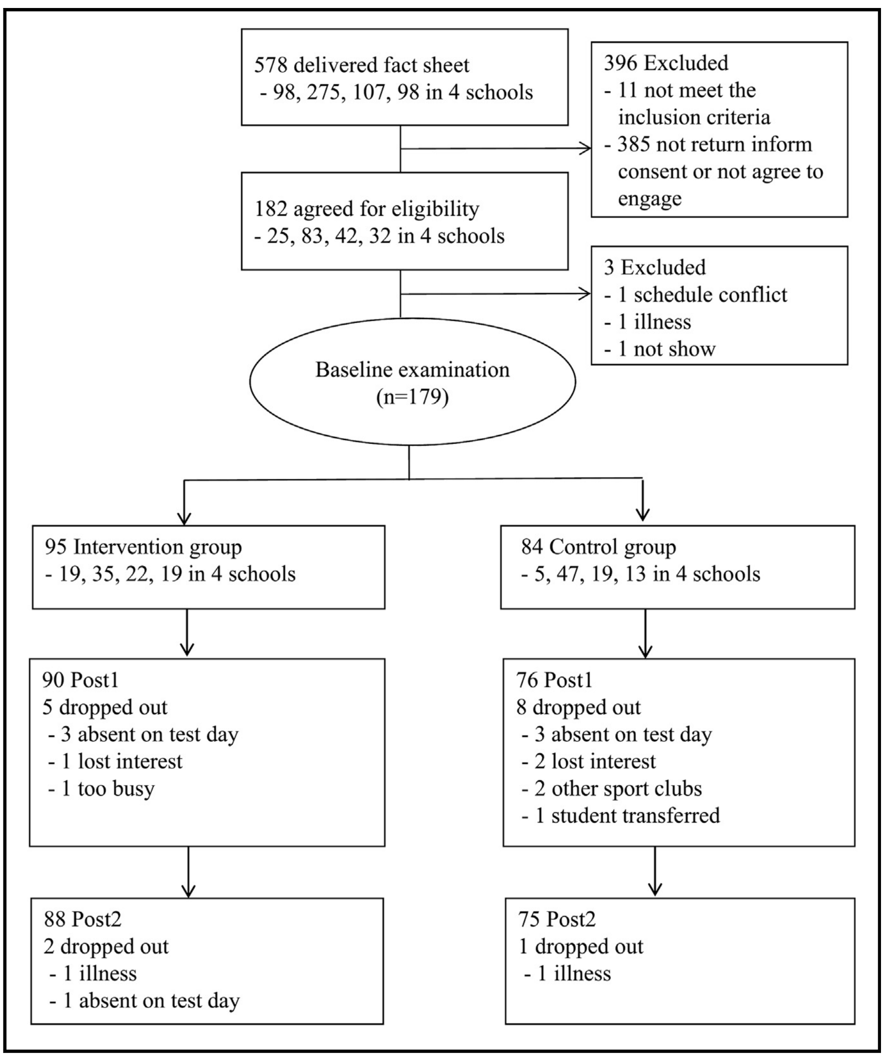

Figure. A CONSORT statement of participants' flow.

DISCUSSION

The authors hypothesized that playing Diab, a health video game with an immersive story, could improve

Table 1. Children's Demographic Characteristics at Baseline

Groups/Variables	Overall (n = 179)	Treatment Group (n = 95)	Control Group (n = 84)	Statistics (χ^2/*t*)	*P*
Gender, n (%)				0.50	.55
Boys	103 (57.5)	57 (60.0)	46 (54.8)		
Girls	76 (42.5)	38 (40.0)	38 (45.2)		
Age, y (n [%])				5.60	.09
8–10	94 (52.5)	42 (44.2)	52 (61.9)		
11–12	85 (47.5)	53 (55.8)	32 (38.1)		
Body mass index, kg/m^2 (mean [SD])	18.93 (3.72)	19.16 (3.76)	18.67 (3.69)	0.88	.38

Note: Pearson's chi-square test of homogeneity was performed for gender and age groups as well as an independent *t* test for body mass index.

children's motivation, self-efficacy, and preference for diet and PA and subsequent health behaviors. Improvements in intrinsic motivation for water, self-efficacy for PA, PA preference, and PAQ-C score were observed immediately after treatment group played the game, whereas these measures decreased in the control group. Thus, Diab motivated children partially with short-term beneficial effects on diet and PA outcomes.

Video games employing immersive virtual reality hold the promise of being effective because they create a virtual environment and provide an engaging experience through interaction with the characteristics that make the narrative personally relevant.[30,31] A higher level of immersion may produce a greater sense of presence, which refers to a user's subjective experience of being there. Higher immersion could produce a greater psychological impact and a higher degree of stimulation.[32] In the current study, immersion scores were positively related to changes in autonomous motivation for PA at post 1 in the treatment group ($r = .27$). Several psychological correlates for diet and PA improved in the high immersion groups and were reduced in the low immersion group at post 1; this suggested that more immersion in G4H would be more effective in improving players' health attitudes. This finding indicates the importance of developing G4H with more immersive narrative to enhance the influence of video game. A notable result was improvements in PA motivation after game playing in the higher immersion group compared with the lower immersion group, but the researchers did not detect an effect of the game on overall motivation in the intervention group. This finding suggested the potential mediation effect of story immersion in the game. As a first step to establish mediation, the association between the immersion score and change of health outcomes was examined to inform the identification of the mediator; however, because of insufficient statistical power, subgroup analysis rather than mediation analysis was performed in this study. Future studies enrolling more participants are recommended to examine potential mediating mechanisms underlying story immersion in Diab and to understand further the link between health video games and health outcomes.

Characters in the video games are important for making players perceive similarity and competence.[33] Children tend to be more receptive to a storyline and therefore could be more influenced by a media context if they perceive similarity to the characters.[34] After playing Diab, Hong Kong children achieved average immersion with a mean score of 37.8 (SD, 9.2), which was lower than a prior study of Diab in US children (mean [SD], 40.8 [8.2]).[11] Diab was created to have diverse characters with different genders, racial origins, body sizes, appearance, and personalities. However, the characters featured African American, Native American, and Hispanic, not Asian children. Although the game demonstrated acceptability and applicability among Chinese children, the dynamic processes of character identification and situation reproduction might have been affected by the cultural adoption. The possible loss of cultural identity between Asian and African American and Hispanic versions could have lowered the immersion level and limited the intervention effect.

Self-determination theory posits that motivation helps individuals initiate and maintain behavior and more self-determined forms of motivation lead to optimal functioning and well-being.[35] Bandura[36] outlined the role of self-efficacy in a model in which the individual engages in a behavior outcome. As such, perceived motivation and self-efficacy could influence aspects of behavior. In the current study, although some psychological correlates improved at post 1, the objective PA level did not demonstrate a positive change in the study. It is possible that increasing the magnitude of these psychological correlates was not powerful enough to engender a behavior outcome as expected. Kelly and colleagues[37] found that behavior change was poorly predicted by self-efficacy for some lifestyle areas. As health-compromising behaviors, poor dietary habits and PA are difficult to change.[38] Even though an individual's intention is assumed to be the best predictor of actual change, often people do not behave in accordance with their intentions.[39] This discrepancy may be the result of several factors, such as unforeseen barriers and environmental influences.[40]

In the current study, the maintenance of improvements in psychological correlates in the treatment group was nonexistent at follow-up, which was 8–10 weeks without exposure to the game. This finding poses a question regarding the sustained effect of the health video game and suggests the need for increased focus to support behavior change maintenance.[41,42] This lack of sustained effect may have resulted from the insufficient short-term improvements on indicators that can not encourage the children to maintain beneficial effects after disconnecting from Diab. Previous reviews of prevention programs indicated that, compared with brief interventions, longer-duration, multiple-session interventions produced superior effects because longer interventions afforded

Table 2. Means (SD) for Measures at 3 Time Points, Stratified by Group and Time Using ANCOVAs

	Baseline		Post 1			Post 2		
Dependent Variables	**Treatment Group (n = 95)**	**Control Group (n = 84)**	**Treatment Group (n = 90)**	**Control Group (n = 76)**	**Adjusted Change[a] (Mean [95% CI])**	**Treatment Group (n = 88)**	**Control Group (n = 75)**	**Adjusted Change[a] Mean (95% CI)**
Intrinsic motivation								
Fruit	24.0 (5.1)	24.7 (4.0)	24.0 (5.7)	23.2 (4.4)	1.6 (0.1 to 3.1)*	23.4 (5.2)	23.4 (5.1)	0.9 (–0.5 to 2.4)
Vegetable	17.4 (4.1)	18.5 (3.6)	17.5 (4.9)	17.4 (3.9)	1.1 (–0.1 to 2.4)	17.1 (4.4)	17.0 (4.1)	1.1 (–0.1 to 2.2)
Water	19.9 (4.6)	20.0 (3.4)	20.3 (4.3)	19.6 (3.7)	1.2 (0.2 to 2.3)*	19.3 (4.2)	19.0 (4.1)	0.7 (–0.5 to 1.9)
PA motivation								
Autonomous	40.1 (12.7)	43.3 (9.9)	40.7 (13.4)	42.2 (12.0)	0.3 (–2.9 to 3.6)	39.3 (13.2)	41.0 (12.7)	−0.3 (−3.4 to 2.8)
Controlled	22.7 (12.3)	19.7 (8.5)	22.4 (12.1)	19.0 (10.9)	2.1 (−1.2 to 5.5)	20.8 (11.8)	18.0 (9.6)	1.2 (−1.9 to 4.3)
Self-efficacy								
Fruit	25.3 (6.7)	24.1 (6.6)	26.5 (6.7)	24.7 (7.1)	1.3 (−0.5 to 3.1)	24.7 (7.6)	24.3 (6.8)	0.3 (−1.7 to 2.3)
Vegetable	16.2 (4.7)	16.6 (4.9)	17.1 (5.5)	16.9 (5.2)	0.3 (−1.0 to 1.6)	16.7 (5.3)	16.4 (4.8)	0.4 (−0.9 to 1.8)
Water	11.7 (3.1)	11.7 (3.0)	12.1 (3.0)	11.5 (3.3)	0.5 (−0.4 to 1.4)	11.8 (2.9)	11.3 (3.0)	0.6 (−0.2 to 1.4)
PA	25.2 (7.6)	26.4 (6.9)	26.5 (7.4)	24.7 (7.6)	2.4 (0.5 to 4.4)**	25.9 (7.5)	25.1 (6.8)	0.9 (−1.1 to 2.9)
Preferences								
Fruit, vegetables, water	112.9 (16.8)	113.4 (16.5)	114.1 (19.3)	114.6 (15.3)	0.1 (−3.9 to 4.1)	116.5 (16.7)	117.0 (15.0)	0.6 (−3.1 to 4.3)
PA	78.5 (12.6)	80.2 (10.7)	81.6 (13.7)	79.9 (11.9)	3.1 (−0.2 to 6.3)	80.2 (13.5)	80.3 (12.7)	1.4 (−2.1 to 4.9)
Physical Activity Questionnaire for Older Children	23.5 (6.5)	25.1 (5.4)	24.9 (6.8)	24.2 (5.6)	1.9 (0.3 to 3.4)*	24.7 (6.6)	23.8 (6.2)	1.5 (−0.1 to 3.1)
Objective PA, min	(n = 85)	(n = 62)	(n = 62)	(n = 46)				
Sedentary[b]	627.8 (78.1)	579.9 (73.5)	610.4 (90.9)	556.4 (70.4)	21.4 (−8.6 to 51.4)	–	–	–
Light PA	158.7 (30.8)	166.0 (34.8)	152.7 (30.1)	162.2 (30.9)	−1.9 (12.8 to 9.0)	–	–	–
Moderate to vigorous PA	40.6 (10.8)	44.2 (15.4)	42.2 (13.3)	43.1 (17.3)	0.7 (−4.0 to 5.5)	–	–	–

CI indicates confidence interval; PA, physical activity.
[a]Adjusted change means and 95% CIs were the differences of the treatment group relative to the control group by ANCOVA adjusted for age, gender, body mass index, social desirability, and baseline assessment of the variable; [b]Indicates variables for which there were baseline differences; *$P < .05$; **$P < .01$.

Table 3. Means (SD) for Measures at 3 Time Points Stratified by Immersion Score Within Treatment Group Using ANCOVAs

Dependent Variables	Baseline		Post 1			Post 2		
	High Immersion (n = 45)	Low Immersion (n = 43)	High Immersion (n = 45)	Low Immersion (n = 42)	Adjusted Change[a] Mean (95% CI)	High Immersion (n = 41)	Low Immersion (n = 41)	Adjusted Change[a] Mean (95% CI)
Intrinsic motivation								
Fruit	24.7 (4.9)	23.0 (5.2)	25.7 (4.6)	22.3 (6.0)	2.2 (0.3 to 4.2)*	24.5 (4.1)	21.9 (6.0)	1.7 (−0.3 to 3.7)
Vegetable	17.8 (4.1)	16.6 (3.9)	18.4 (4.5)	16.7 (5.1)	0.8 (−0.9 to 2.5)	17.6 (4.5)	16.2 (4.3)	0.7 (−0.9 to 2.3)
Water	20.0 (4.7)	19.5 (4.5)	21.4 (3.6)	18.9 (4.6)	2.2 (0.7 to 3.7)**	19.8 (3.9)	18.2 (4.2)	1.4 (−0.1 to 2.9)
PA motivation								
Autonomous	40.2 (12.8)	40.1 (12.8)	42.4 (13.9)	38.9 (12.6)	3.9 (0.3 to 8.1)**	38.7 (13.7)	39.6 (13.3)	−0.3 (−4.2 to 3.6)
Controlled	24.8 (13.0)	20.2 (11.3)	25.0 (12.6)	18.9 (9.5)	4.6 (0.3 to 8.9)**	19.6 (10.4)	19.9 (12.3)	−2.4 (−6.9 to 2.1)
Self-efficacy								
Fruit	25.4 (6.6)	24.7 (6.7)	27.8 (6.4)	25.3 (6.9)	2.4 (−0.1 to 4.9)	25.2 (7.9)	23.3 (7.0)	1.9 (−1.0 to 4.8)
Vegetable	16.3 (4.6)	15.8 (4.8)	17.3 (5.5)	17.1 (5.6)	0.1 (−1.7 to 1.9)	17.0 (5.7)	16.0 (5.0)	0.9 (−0.8 to 2.6)
Water	11.4 (3.4)	11.9 (2.9)	12.1 (3.1)	12.2 (2.9)	0.2 (−0.9 to 1.3)	12.0 (2.9)	11.4 (2.9)	1.1 (0.1 to 2.1)*
PA	25.7 (8.0)	24.3 (7.1)	26.8 (7.8)	26.3 (7.1)	0.0 (−2.2 to 2.3)	25.0 (8.2)	25.8 (6.8)	−0.8 (−3.8 to 2.2)
Preferences								
Fruit, vegetables, water	113.6 (15.3)	112.5 (18.2)	115.4 (20.8)	113.8 (17.0)	1.5 (−4.4 to 7.4)	116.3 (17.5)	116.4 (16.4)	−0.1 (−5.4 to 5.1)
PA	78.4 (13.8)	78.3 (11.4)	81.24 (15.2)	81.6 (12.4)	0.1 (−4.3 to 4.5)	79.2 (14.1)	79.8 (12.6)	0.2 (−4.6 to 5.0)
Physical Activity Questionnaire for Older Children	24.0 (7.1)	23.3 (5.6)	25.3 (7.5)	24.7 (5.9)	0.2 (−1.9 to 2.4)	24.5 (7.2)	23.9 (5.6)	0.4 (−1.6 to 2.4)
Objective PA, minute	(n = 40)	(n = 38)	(n = 34)	(n = 28)				
Sedentary[b]	635.4 (68.0)	595.3 (92.6)	608.8 (102.5)	614.1 (74.8)	−17.9 (−56.6 to 20.8)	–	–	–
Light PA	163.2 (32.4)	152.6 (31.4)	158.6 (29.5)	146.5 (31.3)	0.2 (−14.6 to 14.9)	–	–	–
Moderate to vigorous PA	42.0 (11.6)	39.5 (10.9)	41.2 (10.4)	43.6 (16.0)	−2.5 (−9.2 to 4.1)	–	–	–

CI indicates confidence interval; PA, physical activity.
[a]Adjusted change means and 95% CIs were the differences of the high immersion group relative to the low immersion group by ANCOVA adjusted for age, gender, body mass index, social desirability, and baseline assessment of the variable; [b]Indicates variables for which there were baseline differences; *$P < .05$; **$P < .01$.

the greater opportunity to present information and enhance behavioral change skills.[43] In the development of video games, the concept of energy balance was divided into 18 component skills to be learned sequentially, with the first 9 inserted into Diab and the other 9 inserted into Nanoswarm: Invasion from Inner Space. Playing Diab and Nanoswarm: Invasion from Inner Space led to an increase in fruit and vegetable consumption by about 0.67 servings/d among American children.[12] However, owing to the limitations of the schools' schedules, only Diab was completed in this study. More episodes and a longer duration should be considered in the future to enhance the dosage of the treatment.

The limitations of this study include the nonrandomized design, which may have threatened internal validity and affected generalizability. The further study recruiting participants with equal age distribution in the intervention and control groups was also encouraged to enhance the comparability of 2 groups. Although the existing and previously validated questionnaires were used and demonstrated adequate to excellent internal consistency in this sample, test-retest reliability and criterion validity were not available in target children. More study is needed to further test the advanced psychometric properties of these questionnaires. In additionally, dietary behaviors were not measured owing to operational issues (eg, difficulty in data collection using a recall diet diary among children without parental support, and the unavailability of software for the diet components analysis). Thus, the treatment effect on dietary behavior aspect was not examined, which limited the overall evaluation of the Diab intervention using Diab.

IMPLICATIONS FOR RESEARCH AND PRACTICE

This study found that Diab could help Hong Kong Chinese children partially to improve their motivation, self-efficacy and preference for diet and PA behaviors immediately after completing nine episodes of the game. However, the effect was not maintained 8-10 weeks later. The improvements in psychological influence and behaviors after playing suggest that health video games with appealing characters and immersive stories may have the potential to promote child diet and PA as innovative mediums. However, the lasting effectiveness should be examined with more episodes and longer play duration. Further studies by enrolling more participants are recommended to thoroughly investigate the mediating mechanisms of story immersion in health video game.

Video game entertainment is prevalent in contemporary culture and society and is fully integrated into the lives of many young people. Published studies gradually started to focus on the more interesting alternative aspect of video games: that of their educational potential as teaching and learning tools.[44] Video games have been used in schools to teach education content,[45] nutrition information,[46] alcohol and drug awareness,[47,48] and education about hygiene.[49] The current research using Diab contributed to childhood obesity prevention in the school setting, specifically targeting diet and PA. Video games used in education are labeled parallel Schooling and offer an uninterrupted flow of miscellaneous signs and symbols transmitted via specific stories and activities within the game.[44] School education program may consider applying Diab as an innovative and attractive medium through which to deliver diet and PA knowledge and behavioral modification components.

ACKNOWLEDGMENTS

This research was supported by the General Research Fund from the Research Grants Council of Hong Kong (Grant No. 244913).

REFERENCES

1. Freedman DS, Khan LK, Mei Z, Dietz WH, Srinivasan SR, Berenson GS. Relation of childhood height to obesity among adults: the Bogalusa Heart Study. *Pediatrics*. 2002;109:e23.
2. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med*. 2009;6:e1000058.
3. Thompson D. What serious video games can offer child obesity prevention. *JMIR Serious Games*. 2014;2:e8.
4. Durkin K. Videogames and young people with developmental disorders. *Rev Gen Psychol*. 2010;14:122-140.
5. Thompson D, Baranowski T, Buday R, et al. Serious video games for health: how behavioral science guided the design of a game on diabetes and obesity. *Simul Gaming*. 2008;41: 587-606.
6. de Gortari ABO, Aronsson K, Griffiths M. Game Transfer Phenomena in video game playing: a qualitative interview study. *Int J Cyber Behav Psychol Learning*. 2011;11:15-33.
7. Bizzochi J. Games and narrative: an analytical framework. *Loading*. 2007;1: 5-10.
8. Fisher WR. The narrative paradigm: in the beginning. *J Commun*. 1985;35: 74-89.
9. Schneider G. Resisting narrative immersion. *Studies in Comics*. 2013;4: 333-354.
10. Bowman D, McMahan RP. Virtual reality: how much immersion is enough? *Computer*. 2007;40:36-43.
11. Lu AS, Thompson D, Baranowski J, Buday R, Baranowski T. Story immersion in a health videogame for childhood obesity prevention. *Games Health J*. 2012;1:37-44.
12. Baranowski T, Baranowski J, Thompson D, et al. Video game play, child diet, and physical activity behavior change: a randomized clinical trial. *Am J Prev Med*. 2011;40:33-38.
13. Wang J, Baranowski T, Lau PW, Pitkethly AJ, Buday R. Acceptability and applicability of an American health videogame with story for childhood obesity prevention among Hong Kong Chinese children. *Games Health J*. 2015;4:513-519.
14. Hintze J. *PASS 2008*. Kaysville, UT: NCSS, LLC; 2008.
15. Census and Statistics Department. Hong Kong 2011 population census—summary results. http://www.censtatd.gov.hk/hkstat/sub/sp170.jsp?productCode=B1120055. Accessed May 25, 2016.
16. Bandura A. *Social foundations of thought and action: a social-cognitive view*. Englewood Cliffs, NJ: Prentice Hall; 1986.

17. Ryan RM, Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am Psychol*. 2000;55:68-78.
18. Petty R, Cacioppo J. *Communication and persuasion: central and peripheral routes to attitude change*. New York, NY: Springer-Verlag; 1986.
19. Green MC, Brock TC. The role of transportation in the persuasiveness of public narratives. *J Personality Soc Psychol*. 2000;79:701-721.
20. Deci EL, Ryan RM. Self-determination theory: an approach to human motivation and personality: questionnaires. http://selfdeterminationtheory.org/questionnaires/. Accessed February 7, 2017.
21. Baranowski T, Watson KB, Bachman C, et al. Self efficacy for fruit, vegetable and water intakes: expanded and abbreviated scales from item response modeling analyses. *Int J Behav Nutr Phys Act*. 2010;7:e25.
22. Jago R, Baranowski T, Watson K, et al. Development of new physical activity and sedentary behavior change self-efficacy questionnaires using item response modeling. *Int J Behav Nutr Phys Act*. 2009;6:e20.
23. Domel SB, Baranowski T, Davis H, et al. Development and evaluation of a school intervention to increase fruit and vegetable consumption among 4th and 5th grade students. *J Nutr Educ*. 1993;25:345-349.
24. Sallis JF, Strikmiller PK, Harsha DW, et al. Validation of interviewer-and self-administered physical activity checklists for fifth grade students. *Med Sci Sport Exerc*. 1996;28:840-851.
25. Wang JJ, Baranowski T, Lau WP, Chen TA, Pitkethly AJ. Validation of the Physical Activity Questionnaire for Older Children (PAQ-C) among Chinese children. *Biomed Environ Sci*. 2016;29:177-186.
26. de Vries SI, Bakker I, Hopman-Rock M, Hirasing RA, van Mechelen W. Clinimetric review of motion sensors in children and adolescents. *J Clin Epidemiol*. 2006;59:670-680.
27. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sport Sci*. 2008;26:1557-1565.
28. Adams SA, Matthews CE, Ebbeling CB, et al. The effect of social desirability and social approval on self-reports of physical activity. *Am J Epidemiol*. 2005;161:389-398.
29. Reynolds CR, Paget KD. National normative and reliability data for the revised Children's Manifest Anxiety Scale. *School Psychol Rev*. 1983;12:324-336.
30. Dede C. The evolution of constructivist learning environments: immersion in distributed, virtual worlds. *Educ Technol*. 1995;35:46-52.
31. Green MC. Transportation into narrative worlds: the role of prior knowledge and perceived realism. *Discourse Process*. 2004;38:247-266.
32. Zyda M. From visual simulation to virtual reality to games. *Computer*. 2005;38:25-32.
33. Schunk DH. Vicarious influences on self-efficacy for cognitive skill learning. *J Soc Clin Psychol*. 1986;4:316-327.
34. Burnstein E, Stotland E, Zander A. Similarity to a model and self-evaluation. *J Abnorm Soc Psychol*. 1961;62:257-264.
35. Ryan RM, Deci EL. Active human nature: self-determination theory and the promotion and maintenance of sport, exercise, and health. In: Hagger MS, Chatzisarantis NLD, eds. *Intrinsic Motivation and Self-determination in Exercise and Sport*. Champaign, IL: Human Kinetics; 2007:1-19.
36. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. *Psychol Rev*. 1977;84:191-215.
37. Kelly RB, Zyzanski SJ, Alemagno SA. Prediction of motivation and behavior change following health promotion: role of health beliefs, social support, and self-efficacy. *Soc Sci Med*. 1991;32:311-320.
38. Booth SL, Mayer J, Sallis JF, Ritenbaugh C. Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points. *Nutr Rev*. 2001;59:S21-S36.
39. Sniehotta FF, Scholz U, Schwarzer R. Bridging the intention–behaviour gap: planning, self-efficacy, and action control in the adoption and maintenance of physical exercise. *Psychol Health*. 2005;20:143-160.
40. Schwarzer R. Modeling health behavior change: how to predict and modify the adoption and maintenance of health behaviors. *Appl Psychol*. 2008;57:1-29.
41. Jeffery RW, Epstein LH, Wilson GT, Drewnowski A, Stunkard AJ, Wing RR. Long-term maintenance of weight loss: current status. *Health Psychol*. 2000;19(1 suppl):5-16.
42. Dansinger ML, Tatsioni A, Wong JB, Chung M, Balk EM. Meta-analysis: the effect of dietary counseling for weight loss. *Ann Behav Med*. 2007;147:41-50.
43. Elder JP, Ayala GX, Harris S. Theories and intervention approaches to health-behavior change in primary care. *Am J Prev Med*. 1999;17:275-284.
44. De Aguilera M, Mendiz A. Video games and education: education in the face of a "parallel school.". *ACM Comput Entertain*. 2003;1:10.
45. Watson WR, Mong CJ, Harris CA. A case study of the in-class use of a video game for teaching high school history. *Comput Educ*. 2011;56:466-474.
46. Baranowski T, Cullen KW, Nicklas T, Thompson D, Baranowski J. Are current health behavioral change models helpful in guiding prevention of weight gain efforts? *Obes Res*. 2003;11(suppl 10):23S-43S.
47. Klisch Y, Miller LM, Wang S, Epstein J. The impact of a science education game on students' learning and perception of inhalants as body pollutants. *J Sci Educ Technol*. 2012;21:295-303.
48. Klisch Y, Miller LM, Beier ME, Wang S. Teaching the biological consequences of alcohol abuse through an online game: impacts among secondary students. *CBE Life Sci Educ*. 2012;11:94-102.
49. Farrell D, Kostkova P, Weinberg J, et al. Computer games to teach hygiene: an evaluation of the e-Bug junior game. *J Antimicrob Chemother*. 2011;66(suppl 5):v39-v44.

CONFLICT OF INTEREST

The fourth author of this article (Buday) is the President of Archimage, Inc, the company that created Diab. The rest of the authors have not stated any conflicts of interest.