Evaluating the effectiveness of innovative psychological intervention tools in optimizing health outcomes: A multimethod approach
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Optimizing self-reported healthy food preferences by serious gaming

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Abstract

Serious gaming is an upcoming and promising tool in healthcare practice. The aim of this experimental study was to examine whether health-related serious gaming could optimize food-related outcomes and physical activity. Eighty-one healthy participants (80% female) were randomly allocated to an experimental condition, in which participants played serious games based on transferring information, priming and evaluative conditioning, for half an hour, or a control condition, in which participants played non-health-related computer games. The primary study outcome was self-reported food preference and self-reported food choice, assessed by the Food Choice Task with food pairs differing in healthiness, or in both healthiness and attractiveness. Secondary outcomes were actual food choice and physical activity. A significantly healthier food preference for pairs differing in healthiness was found on the Food Choice Task in the experimental compared to the control condition. No significant differences were found on the other outcomes. This study provides preliminary support for the effects of serious gaming based on optimizing food preferences. More research is needed to confirm the present findings and to further elucidate and optimize the effects of serious gaming on health behaviours.

Introduction

When people are trying to adopt a healthy lifestyle by, for example, improving diet and/or physical activity, they often encounter barriers such as a lack of awareness, knowledge, motivation, and available facilities (54, 55). To overcome some of these barriers, serious gaming, an innovative approach directed at optimizing a healthy lifestyle, can potentially be helpful. Serious gaming has the purpose of educating and motivating users to change behaviours, doing so in an entertaining and engaging manner (25, 26), and distinguishes itself from traditional interventions by the combination of a serious component with a gaming component. Promising aspects of serious games are that they can be used to model positive health behaviours, provide opportunities to virtually engage in practicing health behaviours, transmit information about health, and provide immediate feedback on performance (26, 56). Recently, systematic reviews have provided preliminary support for the effectiveness of serious games on health behaviours. For example, serious games have been shown to increase knowledge about alcohol and other drugs (57) and to improve knowledge and self-management skills in various populations with chronic conditions, such as diabetes, asthma, and cancer (29). One review reported small positive effects of serious gaming on healthy lifestyle promotion and determinants of a healthy lifestyle such as knowledge. However, these results were heterogeneous: The largest effect sizes were found for increased knowledge, whereas smaller effect sizes were found for optimized behaviour change intentions, self-efficacy, and behaviour (28). Overall, these findings suggest that serious games are a useful tool to optimize knowledge concerning health behaviours, though the effects of serious gaming on behavioural outcomes, such as intentions and actual health behaviours, are less conclusive. There is no consensus concerning the duration of a serious gaming session or the number of sessions required to affect health behaviours, since the number and length of gaming sessions varies widely over studies. It has been shown that serious gaming can already be effective in improving health outcomes after one single session, although repeated exposure may lead to stronger effects and, previously, shorter interventions were found to be of lower quality generally (58).

Serious games for mental health often rely on cognitive behavioural therapy (CBT) related principles, which have been shown to be effective in changing health behaviours in adolescents and adults (59, 60). CBT related principles comprise various techniques directed at challenging cognitions underlying dysfunctional behaviours (3), and are furthermore possibly also effective in improving health behaviours such as diet and/or physical activity (61, 62). Serious games for mental health frequently make use of CBT based behaviour change techniques that particularly focus on modifying conscious processes, including education (25). In contrast, innovative behaviour change techniques

that fall outside the awareness of the participant have less often been incorporated in serious gaming paradigms in order to improve diet and/or physical activity. Some attempts show promising effects for some studies, especially in the field of cognitive training for health purposes (i.e., working memory, cognitive inhibition training) as well as cognitive bias modification. One study already combined implicit and explicit behaviour change techniques according to dual processing to improve adolescents' snacking habits, but was not able to improve snack choices (63). Potentially promising techniques for influencing behaviours more automatically are priming and evaluative conditioning. Priming involves exposing people to stimuli without them actually being aware of the influence these stimuli have on their subsequent judgments and behaviours (64, 65). Previous research has demonstrated that participants who were primed with motivating sentences about physical activity showed increased motivation to be physically active and exercised for a longer period (64, 65). In addition, evaluative conditioning involves changing the valence of a stimulus by repeatedly pairing this stimulus with other positive or negative stimuli (66). There is preliminary support for the effect of retraining automatic action tendencies towards unhealthy food items by means of evaluative conditioning with an approach-avoidance training. In this training, participants were repeatedly required to approach healthy food products and avoid unhealthy food products. In a subsequent computer task involving images of chocolate, the trained group showed faster avoidance responses than the control group (67-70). Although the effects of evaluative conditioning and priming on food consumption and physical activity are preliminary and have not yet been evaluated in the context of serious gaming, initial findings are promising. The beneficial effects of altering approach tendencies through evaluative conditioning have also been found in the alcohol domain, in hazardous drinkers as well as in alcoholic patients (71, 72). However, an attempt to incorporate attentional bias retraining into a serious game did not show any effects on self-reported drinking behaviour in heavy-drinking college students (73). In the field of healthy lifestyle, a pilot study investigated the add-on effectiveness of an approach avoidance training on an inpatient childhood obesity program did not find support for the effectiveness for an approach avoidance training in optimizing obesity treatment (74). Further research is needed to investigate the potential of applying evaluative conditioning techniques in serious gaming in combination with other techniques, as combining various behavior change techniques based on dual processing may optimize the effectiveness of serious gaming.

There are various ways to evaluate the effects of serious gaming on health behaviours. Previous research has primarily relied on self-reported outcome measures; however, observations of actual health behaviours could provide valuable additional information about health behaviours, since they are less influenced by demand characteristics than

is the case with self-reported outcome measures (75). Furthermore, previous studies have reported a discrepancy between self-reported intentions to change behaviours and actual health behaviour changes (76, 77). For example, although participants reported that they would choose a healthy snack, when confronted with the actual food choice they only actually chose a healthy snack in 27% of cases (78). For physical activity, also a gap exists between intentions and actual behaviour (79). Factors such as self-efficacy, self-control, and goal-setting are known to play a role in the decision-making processes of health behaviours such as food intake and physical activity: Higher levels of self-control, self-efficacy and goal-setting are related to increased levels of health-promoting behaviours (80-84). As self-reported outcome measures can provide valuable information on the mechanisms preceding an actual choice and observations of actual health behaviors evaluate the actual choice, including factors that play a role in the decision-making process, both self-reported outcome measures and observations of actual health behaviours should be assessed.

The aim of the present study was to evaluate the effects of health-related serious gaming on food-related outcomes and physical activity. In an experimental study, participants were randomly allocated to an experimental condition playing serious games, or a control condition playing non-health-related games for one half-hour session. The primary aim was to investigate whether health-related serious gaming influenced self-reported measures of food preference and food choice. It was hypothesized that participants who played the serious games would have a healthier food preference and make a healthier food choice than the participants who played the non-health-related games. The secondary aim was to explore whether health-related serious gaming influenced actual food choice (i.e., choosing a healthy or unhealthy option) and physical activity (i.e., taking the stairs or the elevator). It was hypothesized that participants who played the serious games would choose a healthy food option more often than participants who played the non-health-related games, and would more often take the stairs rather than the elevator. Factors previously found to be associated with food choice and physical activity, such as self-efficacy, self-control, and goal setting (80-84), were assessed with questionnaires and added as covariates in the analyses where appropriate.

Material and Methods

Participants

Eligible participants were recruited from Leiden University via written and online advertisements from February to April 2016. As the present study is a first proof-of-concept study, we included a rather homogeneous student sample to restrict possible alternative

explanations for the results of serious gaming on food-related outcomes and physical activity. Inclusion criteria were: Being between 18 and 35 years of age and speaking Dutch fluently. Exclusion criteria were: Severe physical or psychiatric conditions (e.g., heart disease, diabetes, and other serious conditions; or Diagnostic and Statistical Manual of Mental Disorders Fourth Edition Text Revision (DSM-IV-TR) psychiatric disorders), body mass index (BMI) ≥ 30 (since obesity is known to be significantly associated with an unhealthy lifestyle (85, 86)), and/or having any food allergies/intolerances. Participants were compensated with either €10 or course credits for their participation.

Design

Participants were randomized to an experimental condition or a control condition. Participants allocated to the experimental condition played serious games, whereas participants allocated to the control condition played non-health-related games. Both gaming conditions were similar in design and all games were provided in three different levels of difficulty. For the experimental condition, games pertaining to food and physical activity domains were used. Those games were derived from a 6-week serious game that was focused on optimizing health outcomes (87). These games (ViaNova©) were specifically developed for this purpose through a partnership between students of Delft University of Technology which were specialized in serious games and game technology, and researchers of the Health, Medical and Neuropsychology Unit of Leiden University. As the 6-week serious game did not only focus on lifestyle factors, but also on other health domains, including relaxation, sleep, cognitions and worldview, only a subset of this 6-week serious game pertaining to food and physical activity was used. Screenshots of each of the serious games and non-health-related games are presented in Appendix 1.

Games

In both conditions, each game started with an instruction screen presenting the aim of the game. This instruction screen could also be consulted at any time during the game. In total, participants played six different games. Those games were played during two sessions of 15 minutes each, separated by a five-minute break. Since the games vary in duration, some of the games were repeated more than once in order to keep the duration of the game sessions half an hour. The order in which participants played the games was random in both conditions for each participant and the number of games participants repeated depended on the speed with which participants read the instructions and completed the games. As an additional reinforcement for motivation during playing the games, participants were always rewarded with a virtual golden, silver or bronze medal at the end of each game depending on their performance.

In the experimental condition**,** participants performed several serious games with different intended strategies, i.e., transferring information, priming and principles of evaluative conditioning. First, to transfer information about health behaviour, participants had to play a game in which health-related facts appeared after making progress in the game. This serious game was repeated three times, with participants receiving a maximum of 12 facts in between playing the game (four facts during each game, e.g., 'being physically active each day for 30 minutes is beneficial for your health' with some examples of how to achieve that goal, such as taking the bicycle instead of the car in order to go to work) in total. Facts were formulated according to the guidelines of the Dutch Health Council. Additionally, two other serious games were directed at priming with healthy items, in which participants had to match three or more of the same healthy food products in a row, and healthy items and words based on food and physical activity had to be found in a newspaper. Finally, three serious games were directed at principles of evaluative conditioning, in which participants had to focus on healthy food products by collecting those items in one game, or had to push and click unhealthy items food and physical activity items away in the two other games. The food products included a broad range of items, with the healthy products including different types of fruits and vegetables (e.g., tomatoes, apples) and the unhealthy products including various high-caloric products (e.g., chips, chocolate). For the items related to physical activity, healthy items were related to exercising (e.g., pictures of people performing exercise) and unhealthy items were related to physical inactivity (e.g., people lying on a couch watching tv). The amount of items presented to participants was fixed in one game (40 items in total; see Appendix 1A), but depended on the speed with which they completed the game, as well as on the level of difficulty in the other games. In the control condition, participants performed six non-health-related games, in which they had to find the exit in a labyrinth and collect some neutral objects on the way to the exit, had to find similar non-health-related pictures, had to fill horizontal lines with different shaped blocks that fell down, had to find a wolf in a crowd of sheep where the wolf was only different from the sheep by a pointed nose, had to break a color code by guessing the pattern of colors, and, finally, had to reach the finish by moving around obstacles and collecting coins on the way to the finish.

Measures

Self-reported food preference and choice
The self-reported food preference and food choice were measured by a computerized Food Choice Task, which was adopted from a previous study (88), in which two products were presented each time. This Food Choice Task consisted of the same food product pairs as used in the study of Salmon and colleagues. These food products were presented

in two different types of tradeoff pairs; three product pairs solely differed in healthiness (i.e., chocolate versus grapes, chocolate cookie versus fruit biscuit, and Dutch caramel waffle versus banana) and three other food product pairs differed in healthiness as well as attractiveness in order to represent a self-control conflict by pairing one tasty, unhealthy food product with a healthy, less palatable food product (i.e., chocolate bar versus cereal cookies, crisps versus rice crackers with peanuts, and crisps versus mixed nuts and raisins) (88). First, participants had to rate for each product of the presented pair how strong their preference was for that specific product on a 7-point scale ranging from 1 (*not at all*) to 7 (*very much*) and subsequently, participants had to indicate which food product they would choose at that moment for each product pair.

Actual food choice

The actual food choice task was based on a previous study in which participants had to choose a snack from a set of four snacks (two healthy and two unhealthy snacks) (78). Participants were told that they could choose a food product that was introduced to them as a gift. A basket with tangerines, apples, candy bars, and pink glazed cakes was presented to the participant. Their food choice was recorded and registered as either healthy (i.e., tangerine or apple) or unhealthy (i.e., candy bar or pink glazed cake).

Physical activity

Physical activity was measured by observing participants' choice between the stairs and the elevator (89). Participants were instructed to move from the first to the fifth floor in order to receive their money or course credits. The stairs and elevator were both located in the same open area in close proximity to each other and were both easily accessible and visible. Their choice in taking the stairs or the elevator in order to move to the fifth floor was recorded. When participants reached the fifth floor, they had to indicate their motivation and intention to take the stairs in the future.

Self-efficacy

The 7-item healthy food factor of the Healthy Eating and Weight Self-Efficacy scale (HEWSE) was used to measure individual differences in self-efficacy (90). Items were judged on a 5-point scale from 1 (*strongly disagree*) to 5 (*strongly agree*), such as 'I am able to consume fruits and vegetables in most of my meals'. Scores can range from 7 to 35, with higher scores indicating higher levels of self-efficacy. The original English version of this questionnaire was translated to Dutch by two independent translators using a forward-backward translation method. A similar internal reliability was found in this study as in the original study (Cronbach's alpha = .81 (90)).

Self-control

The 13-item Brief Self-Control Scale (SCS) was assessed to measure individual differences in self-control on a 5-point scale ranging from 1 (*not at all*) to 5 (*very much*), such as 'I am good at resisting temptation' (81). Scores on this questionnaire can range from 13 to 65, with higher scores indicating higher levels of self-control. The Dutch translation of this questionnaire was used (82), for which a good internal reliability was found in the present study (Cronbach's alpha = .83).

Health behaviour goals and hunger

Healthy eating goal, goal to be physically active, and current level of hunger were measured by three separate items on a 7-point scale ranging from 1 (*not at all)* to 7 (*very much*) (88). Self-reported intention and motivation to take the stairs in future occasions were asked by filling out a 7-point scale from 1 (*totally disagree)* to 7 (*totally agree*) (91).

Procedure

The study procedure was approved by the local psychological ethics committee of Leiden University (CEP16-0222/78) and the study followed the rules stated in the Declaration of Helsinki (2013). Participants provided written informed consent prior to participation. They were told that the experiment consisted of a combination of three independent studies, namely a questionnaire study, a game study, and a food marketing study. This cover story was provided in order to keep participants naive for the actual purpose of the study and to minimize any influence of demand characteristics. Interested participants first completed several online questionnaires considering the inclusion and exclusion criteria, demographics, as well as some other questionnaires that were not relevant for this study aim. If participants were eligible to participate in the study, they were invited for a single lab session guided by a first test leader, which took place at the Faculty of Social and Behavioural Sciences of Leiden University, the Netherlands. First, baseline assessments were made of multiple psychological characteristics, including self-reported self-efficacy, self-control and health behavior goals, as well as some personality questionnaires that were not relevant for this study aim as these were used for educational purposes. Subsequently, participants were randomly allocated, based on a 1:1 allocation ratio as generated by an online random number generator (www.random.org), to the experimental condition or control condition. Participants were unaware of randomization or any differences between conditions during the experiment. During the gaming sessions, the test leader observed whether participants understood the instructions of the games and provided additional explanation concerning the instructions if necessary. After playing the games, participants had to complete the food choice task and completed some personality questionnaires that

were not relevant for this study aim as these were used for educational purposes. Next, participants were instructed to go from the first to the fifth floor of the building in order to receive money or course credits for their participation. Participants were unaware that a second test leader observed participants' choice in taking the stairs or the elevator. When they reached the fifth floor, they had to fill out two questions regarding motivation and intention to take the stairs in the future. They were also told that the study was sponsored by the marketing study and, therefore, they could choose one of the free food products. In fact, participants' choice between a healthy or an unhealthy food product was observed and recorded. At the end of the session, participants were debriefed about the actual purpose of the study and were asked whether they had heard details of the study beforehand other than the details delivered by the study personnel. All participants provided permission to use the observed data.

Data preparation and statistical analyses

Data were analyzed with IBM SPSS Statistics version 23 for Windows (IBM Corporation, Armonk, NY, USA) using a two-tailed significance level of $\alpha < .05$. To test the first hypothesis that participants playing the health-related games would report a healthier food preference compared to the participants playing the non-health-related games, analyses of covariance (ANCOVAs) were performed with food preference as a dependent variable, condition (experimental or control) as a between-subjects factor, and self-efficacy, self-control, and healthy eating goal as covariates. Since ratings of food preference were asked by presenting pairs of products, a relative food preference was computed by subtracting the unhealthy food preference rating from the healthy food preference rating for each product pair and subsequently calculating a sum score for the three pairs. Scores can range from -18 till 18, in which higher scores indicate a healthier food preference. Separate ANCOVAs were conducted for healthiness tradeoff pairs and pairs differing in healthiness as well as attractiveness in which covariates were included. Exploratory, analyses were repeated without inclusion of the covariates in order to elucidate the influence of the covariates. To test the effects of playing serious games on self-reported food choice, a similar approach was used. Analyses were performed with self-reported food choice (number of healthy food choices) as the dependent variable and condition as the between-subjects factor, again separately for healthiness tradeoff pairs and pairs differing in healthiness as well as attractiveness and with and without the above-mentioned covariates. In order to test the second hypothesis that participants playing the health-related games would more often choose the healthy food option than participants playing the non-health-related games, a logistic regression analysis was performed with actual food choice (healthy or unhealthy) as the dependent variable and condition as the between-subjects factor. Self-efficacy, self-control, and healthy eating goal were entered as covariates. To test whether the effects

were comparable after removing the covariates, a Chi square test was conducted with food choice as dependent variable and condition as between-subjects factor. In order to test the third hypothesis that serious gaming will result in taking the stairs more often compared to playing non-health-related games, a logistic regression analysis was performed with physical activity (taking the stairs or the elevator) as the dependent variable and condition as the between-subjects variable. Goal to be physically active was entered as a covariate. To test whether the effects were similar after removing the covariate, a Chi square test was conducted. Furthermore, to test whether intention and motivation to take the stairs in the future differed between the two conditions, an analysis of variance (ANOVA) was performed with the summed score of the two items regarding intention and motivation to take the stairs in the future as a dependent variable and condition as a between-subjects factor. Finally, since the two conditions differed significantly at gender, this factor was incorporated as a covariate in the subsequent analyses.

Results

Baseline characteristics

In total, 104 participants completed the online questionnaire. Twenty-one of them did not meet the eligibility criteria and therefore were excluded from further participation. Two participants did not show up for the lab session. In total, 81 participants (65 females, 80%), with an average age of 21.9 years (SD = 2.6; range 18 – 33) completed the study.

Forty participants were allocated to the experimental condition and 41 participants were allocated to the control condition. Gender significantly differed between the two conditions: 30% of the participants in the experimental condition were male compared to 10% in the control condition, χ^2 (1, N = 81) = 5.24, p = .02. Gender was therefore taken into account as a covariate and significant differences due to gender are reported below. Mean age, BMI, and hunger did not differ between the conditions. Also, no significant baseline differences between the two conditions were found for self-efficacy, self-control, healthy eating goal, and goal to be physically active (all p > .20). The outcomes for the experimental and control condition on the above-mentioned baseline measurements are presented in Table 1.

Table 1. Outcomes of age, gender, body mass index (BMI), self-control, self-efficacy, hunger, healthy eating goal and goal to be physically active, separately for the control condition and experimental condition.

	Control condition	Experimental condition	Significance (p)
Age, M (SD)	21.78 (2.41)	22.06 (2.72)	.63
Gender, n female (%)	37 (90.20)	28 (70.00)	.02
BMI, M (SD)	21.90 (2.88)	22.16 (2.99)	.69
Self-control, M (SD)	41.22 (8.39)	41.23 (8.38)	.99
Self-efficacy, M (SD)	24.85 (5.17)	24.15 (5.78)	.57
Hunger, M (SD)	2.88 (1.54)	2.58 (1.57)	.38
Healthy eating goal, M (SD)	5.46 (1.00)	5.20 (1.18)	.28
Goal to be physically active, M (SD)	5.20 (1.21)	5.15 (1.37)	.88

Note. M = Mean, SD = Standard Deviation

Self-reported food preference

The results for the experimental and control condition on all outcome measures are presented in Table 2. A significant main effect of condition for healthiness tradeoff pairs was found when controlling for self-efficacy, self-control, healthy eating goal, and gender (F (1, 75) = 5.02, p = .03, η^2 = .23). This effect indicated that the experimental condition showed a healthier food preference (M = 3.45, SD = 6.30) compared to the control condition (M = 1.20, SD = 5.54). The covariate self-efficacy turned out to be significant (F (1, 75) = 9.03, p = .004). A significant positive relation between self-efficacy and food preference was found (r = .41, p < .001). Exploratory, after exclusion of the covariates, a marginally significant main effect of condition remained (F (1, 79) = 2.93, p = .09, η^2 = .04; see Figure 1 left panel). No significant main effect of condition for pairs differing in healthiness as well as attractiveness was found on self-reported food preference when controlling for self-efficacy, self-control, healthy eating goal, and gender (F (1,75) = 1.36, p = .25). Exclusion of the covariates yielded similar results (F (1, 79) = .24, p = .63; see Figure 1 right panel).

Table 2. Outcomes on self-reported food preference, self-reported food choice, actual food choice and physical activity, separately for the control condition and experimental condition, without correction for the covariates.

	Control condition	Experimental condition	Significance (*p*)
Food preference H tradeoff, M (SD)	1.20 (5.54)	3.45 (6.30)	.09
Food preference H+A tradeoff, M (SD)	-2.41 (6.85)	-1.63 (7.71)	.63
Food choice H tradeoff, M (SD)	1.88 (0.84)	2.08 (0.83)	.29
Food choice H+A tradeoff, M (SD)	1.39 (0.95)	1.35 (0.98)	.85
Actual food choice, *n* healthy choices (%)	18 (46.15)	21 (55.26)	.42
Actual physical activity choice, *n* taking stairs (%)	17 (41.46)	16 (40.00)	.54

Note. M = Mean, SD = Standard Deviation, H tradeoff = healthiness tradeoff, H+A tradeoff = healthiness as well as attractiveness tradeoff.
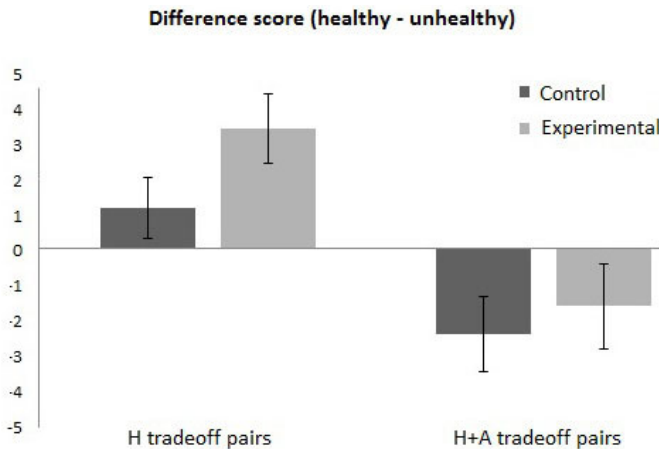

Figure 1. Mean and standard error of the mean for the relative food preference (a higher score on the y-axis represents a more healthy food preference) on healthiness tradeoff pairs (H tradeoff pairs; left panel) and pairs differing in healthiness as well as attractiveness (H+A tradeoff pairs; right panel) in the control condition versus the experimental condition.

In this figure, the experimental condition shows a trend towards a more healthy food preference, compared to the control condition on H tradeoff pairs, but no significant differences are shown for H+A tradeoff pairs.

Self-reported food choice

No significant main effect of condition for healthiness tradeoff pairs was found on self-reported food choice, when controlling for self-efficacy, self-control, healthy eating goal, and gender ($F_{(1,75)} = 1.57$, $p = .22$). Exclusion of the covariates yielded similar results ($F_{(1, 79)} = 1.13$, $p = .29$; see Figure 2 left panel). No significant main effect of condition was found on self-reported food choice for pairs differing in healthiness as well as

attractiveness on self-reported food choice when controlling for self-efficacy, self-control, healthy eating goal, and gender (F (1,75) = .14, p = .71). An explorative analysis excluding the covariates yielded similar findings (F (1, 79) = .04, p = .85; see Figure 2 right panel).
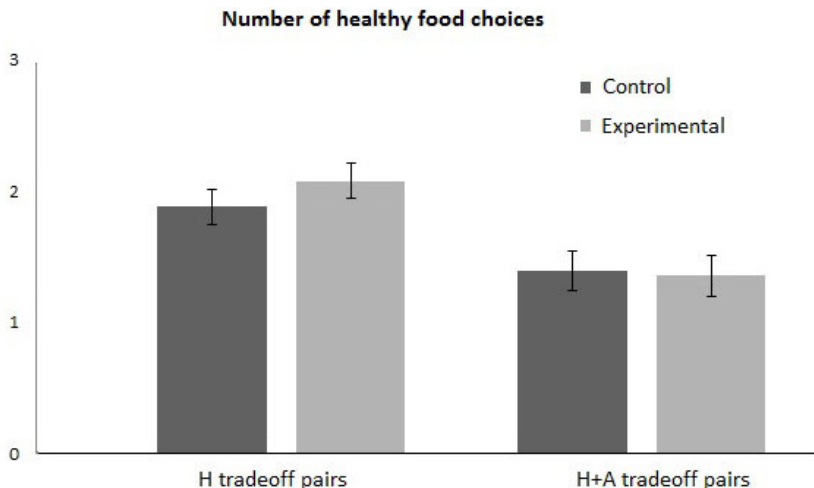

Figure 2. Mean and standard error of the mean for number of self-reported healthy food choices on healthiness tradeoff pairs (H tradeoff pairs; left panel) and pairs differing in healthiness as well as attractiveness (H+A tradeoff pairs; right panel) in the control condition versus the experimental condition.

In this figure, no significant differences are shown between the experimental and control condition in number of healthy food choices on H tradeoff pairs and H+A tradeoff pairs.

Actual food choice

Four participants did not make an actual food choice and were excluded from further data analyses concerning this outcome measure. No significant main effect of condition was found for actual food choice when controlling for self-efficacy, self-control, healthy eating goal, and gender (p = .41). An explorative analysis excluding the covariates also did not find a significant main effect of condition on actual food choice (X^2 (1, N = 77) = .64, p = .42).

Physical activity

No significant main effect of condition was found on physical activity when controlling for goal to be physically active and gender (p = .49). An explorative analysis excluding the covariates yielded a similar finding (X^2 (1, N = 81) = .018, p = .89). An ANOVA on intention and motivation to be physically active revealed no significant main effect of condition (F (1, 79) = .001, p = .98).

Discussion

Serious gaming is an upcoming and promising tool with widespread potential for application in health care. The present study is among the first to incorporate innovative behaviour change techniques of priming and evaluative conditioning into serious gaming in order to investigate the effects on self-reported as well as actual food choice and physical activity. The results provide support for the positive influence of a brief (30-minute) serious gaming session on self-reported food preference with regard to food pairs that differ in healthiness. No significant effects were found after a serious gaming session, however, in relation to food pairs that differ in both healthiness and attractiveness. The present study also yielded no effects on self-reported food choice, actual food choice, actual physical activity, and self-reported intention or motivation to be physically active. The results therefore provide limited support for the use of serious games based on CBT-based behaviour change techniques in the optimization of health behaviours.

In this study, participants reported a healthier food preference after playing serious games than participants playing non-health-related games. Significant results were found for healthiness tradeoff pairs when taking self-efficacy, self-control, healthy-eating goal, and gender into account as covariates. A trend for this finding remained when the analysis was performed without the covariates. Results on the pairs that differed in both healthiness and attractiveness were in the same direction, but no significant effects were found on these pairs after the participants had played either serious games or non-health-related games. Such pairs present a palatable, tasty option that is satisfactory in the short-term in opposition to a healthy option that is beneficial in the longer term (88), giving rise to a self-control conflict. This result suggests that playing brief serious games may not be effective in overcoming a self-control conflict. In addition, no significant differences between the two conditions were found for self-reported food choice. These results suggest that a healthier self-reported food preference does not necessarily translate into a healthier self-reported food choice after participants have played the serious games, which is in line with previous research (78). Also, no significant differences were found for actual food choice or physical activity. These results are in line with the results from a review by DeSmet and colleagues (2014) that show that optimized behaviour changes are more difficult to accomplish than intentions. The finding that playing the serious games does not affect actual behavioural outcomes contrasts with a review by Primack and colleagues, however, that shows that health outcomes can already be improved after a single session of gameplay (58). An important distinction between the present study and the review by Primack and colleagues lies in the population studied and the outcome measures. The present study involved healthy students, who were assessed on health behaviours through self-report as well as observations of actual health behaviours, whereas the review by Primack and colleagues primarily included individuals with various

somatic and psychological conditions, who were assessed on health behaviours with various outcome measures. This may clarify the discrepancy and future research should therefore also evaluate the effects of health-related serious gaming in target populations, such as people with overweight. Though the present study tried to optimize the effectiveness of serious gaming by combining multiple behaviour change techniques based on dual processing, no effects were found on behavioural outcomes. Those limited results are similar to those of a comparable study in the alcohol domain, involving a gamified attentional bias retraining (92) and a pilot study in the domain of optimizing lifestyle factors in children (74). The effects of a brief session of serious gaming based on a combination of behaviour change techniques, therefore, appear to be limited to self-reported food preference in healthiness tradeoff pairs. This is the first variable on which a change can be expected, since it can be seen as a first step towards a healthy food choice. Although the serious games that were played in the present study did not influence participants' actual food choice, previous literature has found that food preference plays an important role in actual food intake, in that the two are highly correlated (93). Possibly, transfer to actual health behaviour changes will take place after repeatedly performing serious gaming sessions, as is also underlined by research stating that learning effects are dependent on practice (94). The present study could therefore serve as a first step forward for future research on the effects of serious gaming incorporating various durations and number of sessions on health behaviours. The finding that self-efficacy was significantly related to self-reported food preference in healthiness tradeoff pairs indicates that participants with a stronger belief in their ability to engage in healthy eating behaviours also tend to have healthier food preferences. This is in line with previous literature demonstrating that self-efficacy is an important predictor of healthy food behaviours and weight control (95-97). Self-control was not significantly related to food preference. Due to the absence of a self-control conflict in the healthiness tradeoff pairs, it can be assumed that self-control does not significantly influence this relationship. This is in accordance with previous research suggesting that the presence of a self-control conflict is required in order to observe the role of self-control in food choices (80, 88). Furthermore, it should be noted that participants in the present study tended overall to have a strong healthy eating goal. This may have limited the role of the healthy eating goal in the relation between serious gaming and food preference.

The present study added several innovative features that are worth highlighting. First, the serious games in the present study consisted of a combination of providing information, priming and evaluative conditioning, which all have shown to be promising in changing health behaviours. By combining those techniques, the present serious gaming sessions relied on a rather strong empirical basis. The present study advances scientific knowledge regarding the effectiveness of serious gaming on health behaviours by combining various

behaviour change techniques based on dual processing, such as priming and evaluative conditioning and including such techniques, for the purpose of strengthening the effects of psychological interventions. Another strength of the present study is that self-reported outcome measures were implemented in combination with observations of actual behavioural outcome measures. By combining different methods of measuring health behaviours, the present study provides a more elaborated view of health behaviour change, contributing to the effects of serious gaming on health behaviours.

It is important also to note some limitations of the present study. First, the study involved a rather highly educated student sample with a high goal to eat healthily, including a large proportion of women. Possibly, by including a less healthy population, the effects of the intervention are more valid. Furthermore, although we aimed to include a rather homogeneous sample to rule out possible alternative explanations for our findings, the present sample was based on students from Leiden University and is therefore not representative for the general population regarding social economic status nor for the target population that needs the actual intervention. Therefore, future studies should also include other populations in order to test the generalizability of the results. Second, as the present study attempted to optimize the effectiveness of serious gaming by combining innovative CBT-based behaviour-change techniques based on dual processing, the current study design does not allow us to disentangle the effectiveness of the separate serious components of the serious gaming sessions. Since serious gaming include both a serious component as well as a fun component, future research should further evaluate the effectiveness of those separate components. Moreover, although beyond the scope of the present study, future research should further elucidate the effectiveness of the fun component of the serious gaming sessions by incorporating a non-gaming control group next to a non-health-related gaming group. Third, the serious games used in the present study is not yet evidence based and did not incorporate certain aspects, such as a storyline and personalization, that have been suggested in the literature to increase the effectiveness of serious games (92); possibly by incorporating these elements into the intervention, this could have been strengthened the effectiveness of the intervention. However, the literature regarding the effective components of serious gaming is still very much in its infancy. Fourth, in addition to the previous limitation, although we do not have indications that the games were not enjoyable for participants, in future studies it should be assessed whether people are engaged when playing the games since engagement is considered to be a major aspect of the effectiveness of these interventions. Nevertheless, it is difficult to properly assess the level of engagement; this field is currently developing rapidly and hopefully we will have good measures available in the nearby future. Fifth, future studies should further vary study duration as well as session frequency in order to see whether serious games could be a

promising stand-alone or add-on tool to CBT-based interventions in healthcare practice. Sixth, although the manipulation of actual physical activity is based on a manipulation used in a previous study (89), the present study is one of the first to incorporate such a manipulation of physical activity into the study design; future research therefore should further examine the psychometric properties of this manipulation. Moreover, it might be that the choice that people made regarding taking the stairs or the elevator affected their subsequent actual food choice, as this choice influences their calorie consumption. Although the calorie consumption may not be substantially altered by this physical activity choice, future studies should take the influence of physical activity on subsequent food choices into account. Seventh, although we have no indications that the cover story was not plausible for participants, filling in the questions regarding physical activity before the actual food choice manipulation may have influenced their food choice by making them aware that the study aimed to evaluate health behaviours. Eighth, although multiple serious games related to food as well as physical activity, the focus of the serious games lays more on food; this may have led to less effective results on physical activity. Ninth, although we controlled for self-reported self-efficacy, self-control and health behavior goals in all analyses, the present study does not have a baseline measurement of food choice and physical activity in order to compare pre to post intervention improvements. Since incorporating these measures could have given away too much information of the actual study aim and could have subsequently affected the outcomes, we chose to not include a baseline assessment on these measures in the current study. As we did not observe any significant differences between the two groups at baseline on self-reported self-efficacy, self-control and health behavior goals, we expect no differences in outcomes when incorporating baseline measurements. Finally, the present study incorporated a question regarding hunger, but in order to more profoundly control for level of hunger in future studies, it would be wise to instruct participants to refrain from eating and drinking for several hours before participation.

In conclusion, our findings cautiously suggest that a short session of serious gaming that incorporates multiple behaviour change techniques including priming and evaluative conditioning can serve as a first step forward in the optimization of health behaviours in healthy participants, by influencing their food preferences. However, taking into account that this study is a first proof-of-concept study, future research should confirm the present findings in order to further elucidate and optimize the effects of serious gaming. Moreover, future studies should evaluate various durations and frequencies of game play, as well as the effects of serious gaming in target populations. In addition, besides self-report outcome measures, it should structurally incorporate actual behavioural outcome measures in order to obtain more insight into the underlying mechanisms and to further optimize the effectiveness of serious games for healthcare practice.

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Appendix 1
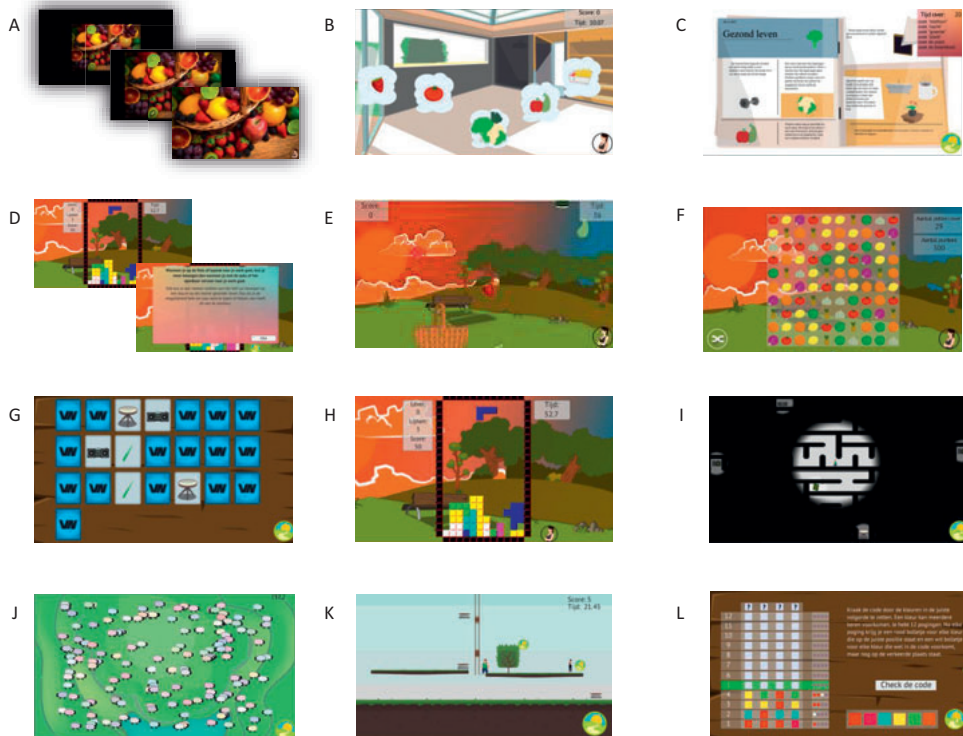
Screenshots of each of the serious games and non-health-related games. (A) Serious game in which participants have to approach healthy items and avoid unhealthy items by using the corresponding arrows on the keyboard; (B) Serious game in which participants had to focus on healthy items by clicking unhealthy items away; (C) Serious game in which participants had to find healthy items and words in a newspaper; (D) Serious game in which participants had to fill horizontal lines with different shaped blocks that fell down and received health-related facts after filling multiple rows; (E) Serious game in which participants had to collect healthy items in a basket; (F) Serious game in which participants had to match three or more of the same healthy food products in a row; (G) Non-health-related game in which participants had to find similar non-health-related pictures; (H) Non-health-related game in which participants had to fill horizontal lines with different shaped blocks that fell down; (I) Non-health-related game in which participants had to find the exit in a labyrinth; (J) Non-health-related game in which participants had to find a wolf in a crowd of sheep where the wolf was only different from the sheep by a pointed nose; (K) Non-health-related game in which participants had to reach the finish by moving around obstacles and collection coins on their way to the finish; and (L) Non-health-related game in which participants had to break a color code by guessing the pattern of colors.