Development and validation of a virtual reality tool for commissioning studies in Food and Nutrition Service

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Abstract. A nutritious, balanced diet has a positive impact on work performance, but the diets of most workers do not meet the recommended intake of vegetables and fruits. Many studies have explored the impact of various food-related cues (e.g., the variety of vegetables). Previous studies have shown that the considerable costs of food-related experiments can be minimized by substituting the real food at the buffet with plastic food. Using this so-called “fake food” does not significantly alter participants’ serving behavior. We leverage this finding to validate our virtual food buffet simulator (VFBS) which conducts the fake food experiment in a virtual environment (VE). The results reveal that the food amounts served in the VE of our VFBS have a high degree of fidelity to the amounts of the same food served in a real buffet. Thus, virtual reality is found to be a reasonable alternative for studies that would otherwise use either real or plastic food. However, our results also indicate that studies regarding such movement behavior conducted in VE should add an extra, compensatory force to correct a faulty programming of the VR tool used in the food experiment. [SNF project 205121_153243].

Keywords. Virtual Reality, Food and Nutrition Studies

1. Introduction

1.1 Motivation

A nutritious, balanced diet has a positive impact on work performance. It enables employees to work more efficiently, allowing for more spare time for private activities. The resulting high yield rate also increases profits for the employer. The advantages brought by maintaining or enhancing one’s personal physical condition are even more beneficial to students (Taras, 2005). Thus, proper management of staff restaurants and student canteens can potentially upgrade both the image and the performance of a corporation or educational institution.

Student canteens and staff dining facilities often serve food buffet-style, one of the most popular means by which to satisfy the diverse diet preferences of customers. This method allows for greater variety at a lower cost. However, the buffet can introduce other concerns—such as excessive intake or unbalanced dietary habits—which can be increasingly problematic even while offering nutritional benefits to students or employees. Offering food allowances, discounts or free food enables a firm to retain excellent employees, but this comes at the risk of ruining the employees’ health. To most people, throwing food coupons into the trash feels like a waste. To avoid this waste, they purchase or serve themselves more food than they need. We want to help workers eat smart and maintain a healthy body while retaining the benefits the buffet brings to both the workers and the company.

1.2 Context

In order to improve health without arousing resentment, we employ unconscious intimation, focusing on such elements as the environmental decor, the arrangement of the food, the variety of food, and the size of the tableware. The variety of vegetables has been shown to be a particular cue that increases the total intake of vegetables at a meal (Meengs et al., 2012). Unfortunately, experiments designed to verify these variables require field studies that involve considerable food preparation along with various changes in environmental decorations. Two alternative methodologies have been proposed to reduce the cost of behavioral experiments: the fake food buffet method (Bucher et al., 2012) and the Digital Human Model (DHM) (Geng et al., 2013). The latter method uses a digital avatar to simulate human behavior and assesses the relative time-consumption of each work cell. While this works for time estimation, it does not suffice for decision-making experiments. In contrast, using fake food (i.e., plastic food) in experimental investigations regarding food service has produced results that are similar to those of studies conducted with real food. The use of reusable fake food allows us to retain the subjects' decisions regarding food service. Thus, we expect that the advantages introduced by fake food can be further developed in a virtual environment (VE). For instance, virtual food (VF) is more environmentally friendly than plastic food. Reshaping, tinting and duplicating VF can be easily accomplished with software, with no need to waste material repeatedly recreating the food.

Computer simulations not only reduce the cost of performing trials but also allow for a wider variety of adjustments to the properties of the food. For example, the friction between foods or the elasticity or viscosity of a certain food can easily be retained or modified. In contrast, maintaining or adjusting the experimental properties of real or plastic food or other elements requires a cook or a professional technician. More importantly, the layout, decoration, and state of the environment can be tightly controlled in virtual reality (VR). A simple button press can reset an entire series of specified conditions, saving a considerable amount of preparation time. VR can even display an instantaneous numerical analysis that can help researchers identify possible influencing factors in real time, which can inform follow-up discussions. Therefore, we propose that the use of VR can actually replace the field study method. We hypothesize that the outcomes of VR studies are no different from those of field studies. This paper assesses and confirms the fidelity and utility of the VR method.

2. Method

2.1 Experimental Design

To validate the VR method, we carried out a comparative study in which a task was performed both in real life and in virtual reality via our VR tool. To benefit from previous findings, we implemented part of an existing study of nutrition behavior (i.e., the fake food experiment) (Bucher et al., 2014) which showed a significant difference between the different proportions of vegetables served. Thus, three types of food were used in our experiment: chicken breast strips, pasta, and carrot sticks. Participants were instructed to serve themselves a meal as they would do at lunch. Two sessions were conducted: a "Virtual Food Session" and a "Plastic Food Session." In both sessions, the amount of each food spooned onto the plate was documented for analysis, along with the serving behaviors that were recorded on video.

2.2 Participants

Thirty-four people participated in our study: 17 females and 17 males. All but three of them were right-handed. The mean age was 29.3 years old, with a standard deviation of 9 years. The average body mass index (BMI) was 22, with a standard deviation of 3.3. All participants were in good health.

2.3 Procedure

Before starting the experiment, the "simulator sickens questionnaire" (SSQ) (Kennedy et al., 1993) was administered to the participants. In accordance with Kennedy et al. (1993), participants whose SSQ scores were higher than 10 were excluded from the study, as they might be susceptible to simulator sickness. Qualified participants were then offered some time to practice with our system. If they reported that everything was fine, the food serving task was started. As previously mentioned, the experiment consisted of a session in the virtual environment (VE) and a session using plastic food.

- In the "Virtual Food Session" (VFS), participants wore our hand tracking system (fig. 1a) and head-mounted display (Oculus, the upper device in fig. 1b). The hand tracking system uses three colored LEDs mounted on the participant's hand, which are detected by a pair of cameras in order to measure hand position and orientation. The hand tracking system enables the participants to control their virtual hand that is presented in the head mounted display. This allows them to operate the virtual spoon, scooping the virtual food from the virtual tray onto the virtual plate (fig. 2). To provide haptic feedback from the virtual spoon, participants held a screwdriver in their hand (fig. 1b).
- In the "Plastic Food Session" (PFS), participants carried out the same serving task in a real physical environment using plastic food (fig. 1c).

The order of the two sessions was randomized. At the end of the experiment, three questionnaires were administered to the participants. The first questionnaire recorded the participants' demographic data and the state of their hunger. The second questionnaire recorded the participants' immersive tendencies, which are used as a baseline [1] in assessing the "feeling" of presence. This feeling of presence was assessed in the third questionnaire. The two latter questionnaires are established instruments in virtual reality research.

2.4 Statistical analysis

After comparing the serving amounts of all types of food, we eliminated two vegetarians from the analysis (n = 32). Our dependent variable, the amount of food served, is analyzed by repeated measure analysis of variance (ANOVA) along with the independent variables, the food types and the "real levels" (VFS and PFS). In VFS, the dependent variable is measured based on how many pieces of virtual food remained on the virtual plate, whereas PFS is calculated by the total served weight of each food divided by the corresponding average weight of the plastic food. Greenhouse-Geisser-corrected results are reported when the general assumptions of ANOVA failed. Effect size (η^2 eta-squared) and observed power (*π*) are reported for all significant results. All examinations are based on a 0.05 significance level. Means, standard deviations (SD), and Pearson correlation coefficients (*r*) are stated as well.

(a) (b) (c)

Figure 1. *The experimental equipment: (a) The hand tracking system consists of three colored LEDs mounted on the hand. Two perpendicular cameras extract and record the position of the LEDs. The position is used to control the virtual hand presented in the virtual reality. (b) The top device in the picture is the head mounted display (Oculus DK2), and the lower device is a screwdriver that is held in the participants' hand to simulate haptic feedback in the virtual food session. (c) The experimental setting of the plastic food (fake food) session*

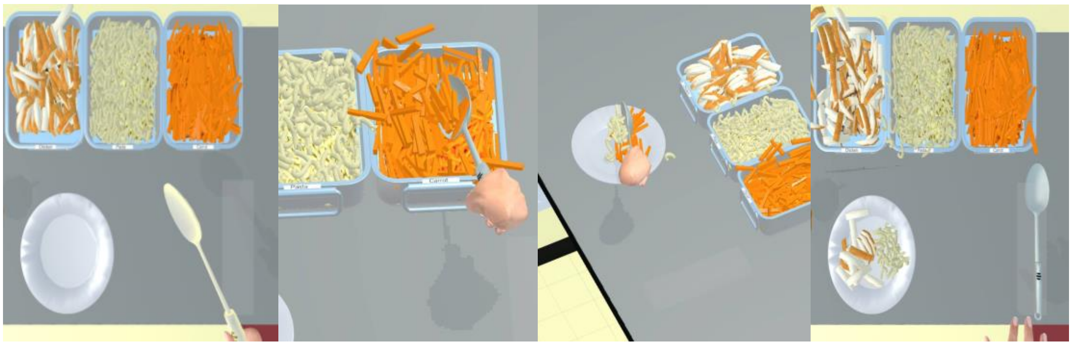

Figure 2. *The serving procedures in the "Virtual Food Session": The pictures from left to right illustrate picking up the spoon, spooning food, serving food, and putting down the spoon to end the virtual food session.*

3. Results

The repeated measure ANOVA of the amount of food served did not detect any significant effect on the "real levels" (RLs), based on Greenhouse-Geisser-corrected data (i.e., the data fails the homogeneity test). The effect of "food type" is found to be significant: $F(1.249,38.704) = 129.71, p < 0.001, \eta^2 = 0.807, \pi = 1.000$. The results of this analysis validate our hypothesis. To improve our VR system, we have also performed post hoc analysis detailing the potential reasons for the results.

The results of pairwise post hoc analysis show a significant difference between each type of food, but no significant effect for the RLs (carrots and pasta, $F(1,31) = 78.269, p < 0.001, \eta^2 = 0.716, \pi = 1.000$; carrots and chicken, $F(1,31) = 74.054, p < 0.001, \eta^2 = 0.705, \pi = 1.000$; pasta and chicken, $F(1,31) = 214.94, p < 0.001, \eta^2 = 0.874, \pi = 1.000$). One-way ANOVA detected no significant effect of age (mean 29.5, SD 9.26). The distributions of each food type served is shown in fig. 3a, and the linear relationships between two RLs of each food type are shown in figs. 3b-d.

Since lunch breaks are usually limited, the food serving time is an essential factor in simulator virtualization. The post hoc analysis across the serving times spent in both sections is $F(1,31) = 64.132, p < 0.001, \eta^2 = 0.674, \pi = 1.000$. The total serving time spent in the VFS (mean 146.47, SD 54.35) is longer than in the PFS (mean 74.12, SD 28.19). We suspect that this time difference is caused by the fidelity to food pliability, and hence analysed the correlation coefficients between the amount of each food taken at each session and the total time taken at each session (table 1).

Table 1. *The Pearson correlation coefficients between the total serving time and the served amount (* indicates there is a significant effect at the 2-tailed 0.05 level)*

	Pasta	**Carrot**	**Chicken**
Total service time in VFS	*r* = 0.349	*r* = 0.223	*r* = 0.408*
Total service time in PFS	*r* =0.244	*r* = 0.183	*r* = 0.366*

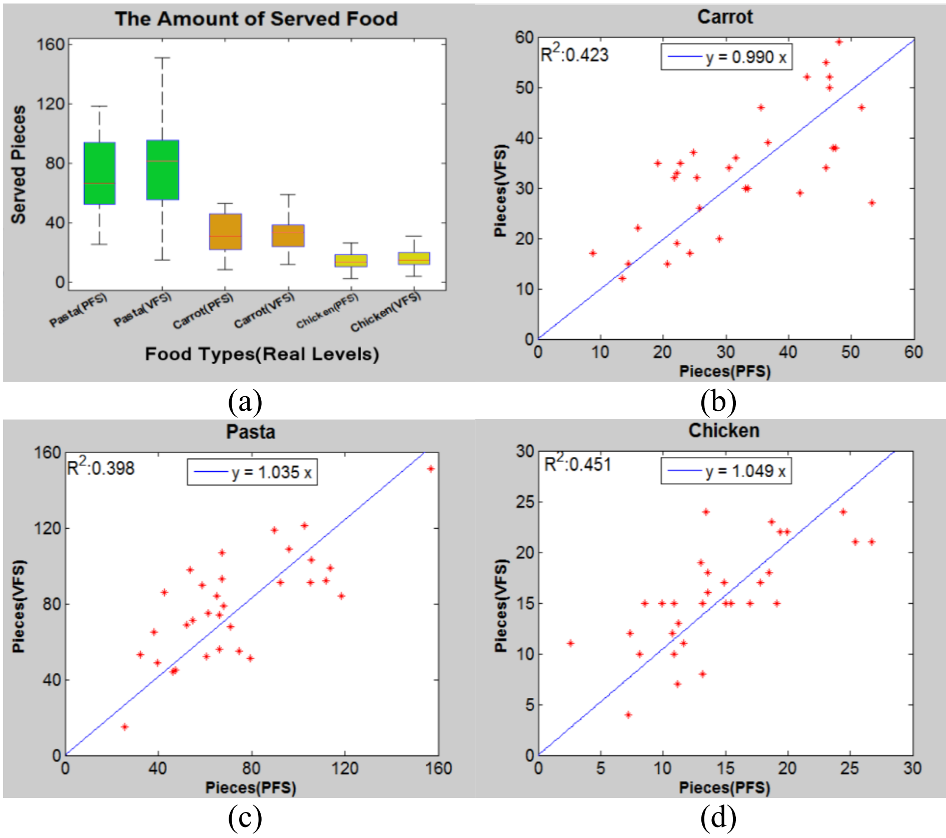

Figure 3. *The relationships between the amount of food served on participants' plate: (a) The served amount distributions of each type of food. (b) The linear regression with suppressing intercept (LRSI) of carrots across the two real levels (RLs). (c) The LRSI of pasta across the two RLs. (d) The LRSI of chicken across the two RLs.*

4. Discussion

These results show no significant differences between real levels, so we retain the null hypothesis: there is no difference between the experimental outcomes of the virtual reality experiment and the fake food experiment. As shown in fig. 3a, the distributions of food intake during the two RLs are very similar. The linear relationships between the amounts of food taken in each RL (figs. 3b-3d) show that the food intake amount can be predicted on a one-for-one basis according to the slope of the regression line.

As for the serving time, the effect of RL is significant. Based on the information obtained from the video observation and participants' reports, we make a sub-hypothesis. Pliability was sacrificed for the sake of efficiency in the program's physical engine and the resulting rigidity prohibits the virtual food from undergoing the kind of deformation that is normal in real food. The absorbed force is released as a counterforce. The increased reaction strengthens the elastic force and causes the VF to bounce off the utensil. Participants who wish to serve the same amount of food in both the virtual and real environments must increase the number of times that food is spooned out of the tray in the VE. As Table 1 shows, the correlation between the served amount of food and the serving time increases in the VFS. The difficulty of picking up virtual food lengthens the serving time in the VE.

5. Conclusion

Overall, the virtual environment does indeed allow for people's decisions to be retained. Our virtual reality simulator can be used to conduct quantitative analysis studies. In other words, our virtual reality simulator provides enough authentic information to effectively replace the original environment. Information from the artificial environment does not cause people to make decisions that differ from those they make in the real world. The outcome of the virtual reality simulator shows a high level of fidelity to actual consequences.

However, our research data shows that there is still room for improvement. This simulator does not precisely mimic the serving movement in the real world. A defect in the program's physical engine causes the virtual food's reaction force to be stronger than that of real food. This extra force causes the virtual food to overreact to the collision and, thus, fall out of the virtual spoon. As a result, each virtual spoonful holds less food, lengthening the total service time. To more accurately simulate the natural physical phenomena, we propose adding an extra, compensatory virtual force to every virtual object with which the user interacts.

6. References

Bucher T, van der Horst K & Siegrist M. (2012). "The fake food buffet – a new method in nutrition behaviour research." British Journal Nutrition 107, 1553–1560.

Geng J, Chuan Lv, Dong Zhou, Ying Li, Zili Wang. (2013). "Compensation-based methodology for maintenance time prediction in a virtual environment." Simulation Modelling Practice and Theory 47, 92-109

Howard Taras. (2005) Nutrition and Student Performance at School. Journal of School Health, 75(6): 199-213

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). "Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness." The International journal of aviation psychology 3(3), 203-220.

Meengs JS, Roe LS & Rolls BJ (2012) Vegetable variety: an effective strategy to increase vegetable intake in adults. J Acad Nutr Diet 112, 1211–1215.

T. Bucher, M. Siegrist, K. van der Horst. (2014). "Vegetable variety: an effective strategy to increase vegetable choice in children." Public Health Nutrition, 17 (06), 1232–1236.