Appetite 153 (2020) 104741

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

# Validation of a Virtual Reality Buffet environment to assess food selection processes among emerging adults

Charissa S.L. Cheah[a,*], Salih Barman[a], Kathy T.T. Vu[a], Sarah E. Jung[a], Varun Mandalapu[b], Travis D. Masterson[c], Ryan J. Zuber[d], Lee Boot[d], Jiaqi Gong[b]

[a] Department of Psychology, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD, 21250, USA
[b] Department of Information Systems, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD, 21250, USA
[c] Department of Nutritional Sciences, The Pennsylvania State University, 110 Chandlee Laboratory, University Park, PA, 16802, USA
[d] Imaging Research Center, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD, 21250, USA

ARTICLE INFO

*Keywords:*
Virtual reality
Food buffet
Food selection
Emerging adults

ABSTRACT

Emerging adulthood is a critical developmental period for examining food- and eating-related behaviors as long-term weight-related behavioral patterns are established. Virtual reality (VR) technology is a promising tool for basic and applied research on eating and food-related processes. Thus, the present study tested the validity and user perceptions of a highly immersive and realistic VR food buffet by: (1) comparing participants' food selections made in the VR buffet and a real-world (RW) food buffet cafeteria one-week apart, and (2) assessing participants' rated perceptions of their VR experience (0–100 scale). Participants comprised an ethnically diverse sample of emerging adults ($N = 35$, $M_{age} = 20.49$, $SD = 2.17$). Results revealed that participants' food selections in the VR and RW food buffets were significantly and positively correlated in Kcals, grams, carbohydrates, and protein (all $p$'s $< 0.05$). Moreover, participants perceived that: (a) the VR buffet was natural ($M = 70.97$, $SD = 20.92$), (b) their lunch selection in the VR buffet represented a lunch they would select on an average day ($M = 84.11$, $SD = 15.92$); and (c) their selection represented a lunch they would select if the same foods were available ($M = 91.29$, $SD = 11.00$). Our findings demonstrated the validity and acceptability of our highly immersive and realistic VR buffet for assessing food selection that is generalizable to RW food settings one-week apart without precisely matched foods. The findings of this study support the utility of VR as a validated tool for research on psychological and behavioral food-related processes and training interventions among emerging adults.

## 1. Introduction

Long-term weight-related behavioral patterns, such as eating habits, are established during the period of emerging adulthood (18–25 years of age; Arnett, 2000), and there is a corresponding increase in obesity prevalence during this period (Gordon-Larsen, Adair, Nelson, & Popkin, 2004; Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008; Park, Paul Mulye, Adams, Brindis, & Irwin, 2006). Moreover, emerging adults have an elevated risk for engaging in adverse health behaviors, including dysfunctional eating behaviors and eating disorders (American Psychiatric Association, 2013; Nelson et al., 2008; Racette, Deusinger, Strube, Highstein, & Deusinger, 2008; Sussman & Arnett, 2014). Therefore, emerging adulthood is a critical developmental period for examining food- and eating-related behaviors, which can ultimately inform prevention and intervention efforts. Emerging technologies, such as virtual reality, may provide a unique way to further understand and intervene in aberrant eating behaviors.

Due to the increasing rates of obesity and disordered eating for emerging adults and the associated comorbidities (e.g., heart disease and diabetes), researchers have argued for a closer examination of nutrition and eating behaviors to promote healthier eating patterns (Anderson, Shapiro, & Lundgren, 2003; Crombie, Ilich, Dutton, Panton, & Abood, 2009; Vadeboncoeur, Townsend, & Foster, 2015; Vella-Zarb & Elgar, 2009). Beyond self-reported measures of food choices, other common methods to study personal food choices include assessments of: (1) real food choice in a laboratory or in real-life settings (Fernandes

* Corresponding author.
*E-mail addresses:* ccheah@umbc.edu (C.S.L. Cheah), sbarman1@umbc.edu (S. Barman), kvu1@umbc.edu (K.T.T. Vu), jungsar1@umbc.edu (S.E. Jung), varunm1@umbc.edu (V. Mandalapu), travis.d.masterson@psu.edu (T.D. Masterson), zuj1@umbc.edu (R.J. Zuber), boot@umbc.edu (L. Boot), jgong@umbc.edu (J. Gong).

https://doi.org/10.1016/j.appet.2020.104741
Received 28 January 2020; Received in revised form 7 May 2020; Accepted 13 May 2020
Available online 20 May 2020
0195-6663/ 

et al., 2016; Fisher & Birch, 1999; Zellner et al., 2006); (2) food choices from photos or menus (Balcombe, Fraser, & Falco, 2010; Peschel, Orquin, & Mueller Loose, 2019); and/or (3) food choices from food replicas in fake food buffets (Bucher, van der Horst, & Siegrist, 2012). Each of these approaches have limitations, including the high cost and limited selection of real food and food replicas, which impact the generalizability of these findings to real world behaviors (Ung, Menozzi, Hartmann, & Siegrist, 2018). In addition, although conducting experimental studies in laboratory settings with a limited set of real food, photos, or food replicas increases internal validity as researchers have greater experimental control and manipulation over variables of interest, the lack of contextual cues may limit ecological validity and the generalizability of research findings for eating-related processes (Gutiérrez-Maldonado, Wiederhold, & Riva, 2016).

### 1.1. Virtual reality food buffets

Recently, virtual reality (VR) technology has been utilized to study issues related to eating and food-related processes because this technology has been shown to overcome some of the aforementioned limitations (e.g., Gorini, Griez, Petrova, & Riva, 2010; Marcum, Goldring, McBride, & Persky, 2018; Persky et al., 2019; Persky, Goldring, Turner, Cohen, & Kistler, 2018; Ung et al., 2018; Yaremych, Kistler, Trivedi, & Persky, 2019). VR technology immerses individuals within computer-generated environments that update adaptively to the users' head and/or body motion (Parsons & Rizzo, 2008). Researchers can create immersive and naturalistic VR environments that enables better generalizability of findings to the real world (RW) settings compared to controlled laboratory studies (Forman et al., 2018). Specifically, VR buffets allow researchers greater control over the buffet environment by manipulating environmental factors (e.g., food color and texture, and presence of other people) and using a variety of automatic measurements assessing the order, timing, and other food selection details (Marcum et al., 2018). Thus, researchers and clinicians have more recently looked to VR food buffets as a promising tool for both basic and applied research on eating and food-related processes.

### 1.2. Virtual Reality Buffet validation studies

In order to illustrate the utility of VR for research and clinical work, studies have assessed the internal and external validity of VR technology by comparing food selections in VR with food selections in RW settings. For instance, Persky et al.'s (2018) study examining parents' food selections for their children in VR and RW buffets revealed that the caloric content of parents' selections of virtual and real pasta servings were highly correlated, demonstrating that the VR buffet had convergent validity. Moreover, parents reported feeling that: (1) the VR buffet was moderately like the real world; (2) they would be likely to serve the meal they chose in the VR buffet to their child; and (3) the meal they chose was representative of how they would normally feed their focal child from a buffet in terms of both the amount and healthfulness of the food (Persky et al., 2018).

In Ung et al.'s (2018) study with adults, participants' selections in a VR food buffet and their selections in a RW simulation food buffet using fake food models were highly correlated, suggesting that the relative amount of foods served in the VR food buffet and RW simulation food buffet were comparable. In these previous studies, participants were asked to select the serving size of the same food items found in both VR and RW, and to make selections in both environments within minutes of the first selection. Specifically, in Persky et al.'s (2018) study, participants first selected a pasta serving and chose from three cup sizes of apple juice in VR and then approximately 3 minutes later, were asked to select a pasta serving and choose from three cup sizes of apple juice in RW. Similarly, Ung et al. (2018) asked participants to select servings of carrots, pasta, and chicken in VR and then 5 minutes later, to select servings of replicas of carrots, pasta, and chicken (i.e., fake food).

The present study proposed to extend these previous VR buffet validation studies through comparing the food selection process in a highly immersive and realistic VR environment and a RW food buffet cafeteria one-week apart. Specifically, by weighing RW foods and using available advanced photogrammetry technology and modeling, we were able to create a hyper-realistic cafeteria environment and foods in VR based off a RW cafeteria and foods (see Method for virtual environment creation). Similar to prior studies, the present study also aimed to compare emerging adults' food choices in VR and RW environments. However, in our validation study, participants selected from a wide selection of foods available in both the VR and RW buffets that were not specifically matched in order to maximize the ecological validity and generalizability of our findings. In fact, because the RW setting was an actual cafeteria on the college campus, we had no control over the lunch selection available on the day that the participants were scheduled. In addition, instead of correlating the food serving size of selections that participants made minutes apart, we correlated the nutritional content of their food selections in the VR and RW environments that were made one-week apart, which provides stronger evidence for the generalizability of food choices in VR to RW settings.

### 1.3. The present study

The overall goal of the present study was to test the validity of and user experience with the VR food buffet in assessing food selection. To accomplish this, emerging adults were asked to select a lunch meal within two conditions, in a RW campus dining hall buffet and in a VR environment designed to mimic the campus dining hall buffet.

The primary aim of the present study was to assess convergent validity by examining the correlations between the nutritional content of participants' food selections in the VR buffet and their RW food buffet selection (in Kcals, grams, fat, carbohydrates, protein) one-week apart. We hypothesized that the nutritional content of participants' food selections in the VR and RW buffets would be positively correlated. The second aim was to assess user experience in the VR environment. Specifically, we examined participants' perceptions of the VR buffet in terms of: (a) how natural was their overall experience in the VR buffet; (b) how much their final selection in the VR buffet represented a lunch that they would select and eat/drink on an average day; and (c) how much their final selection represented the lunch that they would select and eat/drink if the same food selection was available. We predicted that participants would rate their experiences in the VR buffet as natural and representative of their typical behaviors.

## 2. Method

### 2.1. Participants

A total of 35 students (20 females), between 18 and 25 years old ($M$ = 20.49, $SD$ = 2.17), attending a mid-sized state university in the Mid-Atlantic region of the United States completed both VR and RW phases of our study. The specific demographic characteristics of the sample are presented in Table 1.

### 2.2. Procedure

The study protocol consisted of three phases: A questionnaire phase, VR buffet phase and RW buffet phase. All study procedures were approved by the Institutional Review Board of University of Maryland, Baltimore County (Understanding Healthy Development in Young Adults, protocol #: Y19CC20012). Before the start of each phase, participants were briefed on the study protocol and provided written consent. In the first phase, the participants completed an online questionnaire for a larger study assessing health development during emerging adulthood, which included a demographics questionnaire used in the current study analyses. Next, participants were screened for

**Table 1**
Demographic characteristics of the sample.

| | *N* (%) | *M* (*SD*; Min - Max) |
|---|---|---|
| Total *N* | 35 | |
| (Cis) Females | 20 (57) | |
| (Cis) Males | 15 (43) | |
| Race/Ethnicity | | |
| White | 15 (43) | |
| Asian | 10 (29) | |
| Black/African American | 5 (14) | |
| Hispanic/Latinx | 1 (3) | |
| Bi/Multicultural | 1 (3) | |
| Other | 3 (8) | |
| Living Situation | | |
| On Campus | 12 (34) | |
| Off Campus with Family | 13 (37) | |
| Off Campus without Family | 10 (29) | |
| BMI | | 23.60 (5.08; 17.70–42.17) |
| Underweight (BMI < 18.5) | 3 (9) | |
| Normal weight (18.5 < BMI < 25) | 25 (71) | |
| Overweight (25 < BMI < 30) | 4 (11) | |
| Obese (30 < BMI) | 3 (9) | |
| Age | | 20.49 (2.17; 18–25) |

whether they suffered from motion sickness, were allergic to latex or alcohol wipes, have epilepsy or experienced a seizure, have ever experienced extreme discomfort from a VR experience or been told that they should avoid VR experiences for medical reasons, and if they wear glasses or contact lenses. Participants were asked about glasses or contact lenses because the RW phase of the study required participants to wear eye-tracking glasses, which could not be worn together with eyeglasses. Eye tracking data was not analyzed in this study. Those who indicated that they wear glasses or lenses are also asked whether they were able to wear contact lenses during their session or were able to see well enough without glasses to participate in this study. Individuals who indicated that they experienced motion sickness, had latex and alcohol wipe allergies, had medical conditions or could not participate without wearing glasses were not eligible to participate in the VR and RW buffet phases. Eligible and interested participants were assigned to undergo either the VR or RW buffet phase first and the other phase one-week later in a counterbalanced order.

To validate the VR methodology, similar to Persky et al. (2018), we carried out a comparative study in which the same task was performed in both the VR and RW buffet. Unlike previous studies, our participants performed the VR and RW phases one-week apart rather than within a single laboratory visit. All VR buffet or the RW buffet sessions were conducted during the lunch period, between 11AM and 2PM. Participants were asked to fast for 4 hours prior to both phases and received text message reminders 4.5 hours before coming to their appointments. At the beginning of each phase, participants were asked to rate their current level of hunger using a visual analogue scale (0 = *Not at all* to 100 = *Most they have ever been*).

In the VR phase, the participants first received a scripted training on the VR environment and how to interact with the system for approximately 5 minutes. Participants were instructed: (1) to look at each of the food options so that they would know the range of choices available; and (2) on how to interact with specific food options to familiarize them with how to pick up the food, change the portion size, place the food/drink on/in the plate/bowl/cup and discard foods that were unwanted or selected erroneously by putting them in a trash can. Specifically, participants were instructed to select broccoli and decrease the portion size to the smallest; select Cajun chicken and increase the portion size to the largest; pick up a slice of pizza; fill a bowl with tomato soup; fill a cup with orange juice; and select white pasta and marinara sauce during the training. Participants were then instructed to make food selections for lunch as they would normally in real life. The software automatically logged the portion size of each food selected once the participant placed their final selection at the register. Participants could use as many plates, bowls and cups as they wanted.

The RW phase was conducted in a food buffet cafeteria at the university during the lunch period, where a wide variety of foods from appetizers to desserts were served daily. Similar to the VR phase, participants were first instructed to explore all the foods in the buffet. Next, they were asked to make food selections for lunch as they would normally. Participants could select as many plates, bowls, and cups as they wanted and were instructed to bring their final selections to the research assistants who then separated and weighed each food item individually and recorded the corresponding serving amount. Participants were then allowed to eat their selected meal.

When participants indicated that they had finished their food selections at the end of both the VR and RW phases, they were asked, “Are you sure that you have gotten everything that you think you will eat during lunch, including additional plates, desserts, and drinks? Do you want to go through and look again?” to ensure that participants were able to choose all the food items they wanted. Data collection for the food selections ended when participants confirmed that they were done with their food selection.

After completing the food-selection portion of both the VR and RW phases, participants responded to three questions using a visual analogue scale (0 = *Not at all* to 100 = *Completely*); “(a) How natural was the overall experience?”, “(b) How much did your final selection represent the lunch that you would select and eat/drink on an average day?” and “(c) How much did your final selection represent the lunch that you would select and eat/drink if the same selection was available?”

### 2.3. Materials

#### 2.3.1. Virtual environment creation

The process of photogrammetry was utilized throughout the asset and environment creation pipeline to acquire accurate references for creating architectural structures of the buffet environment. Numerous photographs were carefully taken of the inside of the campus cafeteria. Walls, floors, and ceiling surfaces were scanned, as were the buffet tables and accessories including cups, plates, bowls, etc. Images were filtered for optical quality and photographic data was used to reconstruct a 3D mesh and color texture for each object. In addition to the 3D modeling, contextual cues such as dining hall sounds (clinking of spoons, talking, etc.) were recorded at the cafeteria. These sounds were played while the participants interacted with the VR Buffet to simulate the background noise of the cafeteria. Images of both the real and virtual environment can be seen in Fig. 1.

#### 2.3.2. Food buffet item selection and modeling

The primary goal when selecting and creating food items for the virtual environment was to ensure that food items were accurately sized and textured and represented a variety of food options that would be typically found at the RW buffet. Therefore, foods for the virtual environment were initially selected from the semester long lunch menu of the campus cafeteria obtained from the campus caterers (Chartwells). A variety of main dishes, side dishes, deserts, and drinks were selected. Typical variations of food items were also determined to increase the range of options and provide variations in energy density (e.g., brown rice compared to fried rice) and perceived healthfulness (e.g., pepperoni pizza compared to veggie pizza). A full list of food items and their nutritional values were listed in Table 2. Average weights of each food at each portion size were provided in Supplementary Table 1.

Once the food items were selected for use in the VR environment, the food was obtained and prepared by study team members. Then, the prepared food was scanned with photogrammetry (see Figs. 2 and 3) and carefully measured by hand to produce accurate volume measurements of each item (see Fig. 4). The photographic data of the foods was used to 3D model each food realistically and accurately so that the

**Fig. 1.** Real-world (left) and virtual reality buffet (right) environments.

**Table 2**
Estimated Nutritional Values per 100 g.

| Foods | Kcals | Fat (g) | Cho (g) | Protein (g) |
|---|---|---|---|---|
| Veggie pizza bites[a] | 222 | 7.74 | 30.37 | 8.27 |
| Cheese pizza[a] | 259 | 11.24 | 28.17 | 11.36 |
| Pepperoni pizza[a] | 253 | 12.32 | 25.15 | 10.48 |
| Whole grain pasta[b] | 149 | 1.71 | 30.07 | 5.99 |
| White pasta[a] | 158 | 0.93 | 30.86 | 5.80 |
| Marinara sauce[b] | 62 | 2.02 | 10.82 | 1.57 |
| Alfredo sauce[a] | 332 | 30.98 | 8.34 | 6.07 |
| Low calorie pasta sauce[a] | 152 | 10.51 | 8.58 | 5.96 |
| Fried rice[a] | 162 | 4.78 | 18.40 | 4.17 |
| Whole grain rice[b] | 123 | 0.97 | 25.58 | 2.74 |
| White rice[b] | 130 | 0.28 | 28.17 | 2.69 |
| Braised beef[a] | 250 | 15.11 | 0 | 26.72 |
| Cajun chicken[a] | 173 | 4.51 | 0 | 10.91 |
| Grilled salmon[a] | 178 | 8.20 | 0 | 24.30 |
| Black beans[a] | 152 | 2.77 | 23.71 | 8.88 |
| French fries[a] | 291 | 16.17 | 34.84 | 2.97 |
| Sweet potato fries[a] | 167 | 8.69 | 21.44 | 1.65 |
| Wheat dinner rolls[a] | 272 | 6.29 | 46.46 | 8.60 |
| White dinner rolls[a] | 310 | 6.47 | 52.04 | 10.86 |
| Steamed green beans[b] | 53 | 3.01 | 6.45 | 1.52 |
| Roasted carrots[b] | 60 | 3.30 | 7.73 | 0.62 |
| Steamed broccoli[b] | 46 | 2.20 | 5.35 | 3.12 |
| Mashed potatoes[b] | 115 | 4.36 | 17.78 | 1.80 |
| Gravy[b] | 35 | 1.09 | 5.49 | 0.78 |
| Bread sticks[a] | 312 | 10.51 | 45.67 | 8.18 |
| Tomato basil soup[b] | 36 | 0.11 | 8.40 | 1.01 |
| Broccoli cheddar soup[b] | 72 | 3.52 | 7.48 | 2.51 |
| Grapes[b] | 69 | 0.16 | 18.10 | 0.72 |
| Strawberries[b] | 32 | 0.30 | 7.68 | 0.67 |
| Apple slices[b] | 52 | 0.17 | 13.81 | 0.26 |
| Chocolate pudding[b] | 129 | 3.40 | 21.32 | 3.38 |
| Chocolate chip cookies[a] | 487 | 26.70 | 62.12 | 4.67 |
| Lemon bars[a] | 453 | 21.42 | 61.75 | 4.80 |
| **Beverages** | | | | |
| Coke[b] | 37 | 0.02 | 9.56 | 0.07 |
| Diet Coke[b] | 2 | 0.03 | 0.29 | 0.11 |
| 2% milk[b] | 50 | 1.98 | 4.80 | 3.30 |
| Orange juice[b] | 46 | 0.13 | 11.30 | 0.10 |
| Iced tea[b] | 42 | 0 | 10.76 | 0 |
| Water | 0 | 0 | 0 | 0 |

Note.
[a] High energy dense foods (> 1.5 kcal/g).
[b] Low energy dense foods (≤1.5 kcal/g).

dimensions of the model matched their real-world counterparts. This process also ensured that participants' visual perception of the food including the volume of space it occupied in the VR environment would be accurate to the real world.

The food assets that could not be created from photogrammetric sources were modeled in a computer animation and modeling software, Autodesk Maya (Version 2018.2, 2018). The food items that were modeled using Maya included braised beef, Cajun chicken, roasted carrots, steamed broccoli, green beans, white and whole grain pasta, chocolate pudding, French fries, sweet potato fries, veggie pizza bites, apple slices, grapes, and strawberries. Although these foods were not directly created with photogrammetry, samples of the real food items were acquired and measured to ensure that our 3D models were matched to RW foods in volume.

To better approximate the appearance of RW food, style guides were created for each food. These style guides ensured that food textures appeared appealing and realistic. In addition, for unit items such as carrots or french-fries, models that varied in size were created to better reflect RW food variation for multi item presentations. Following the creation of individual models, pre-made portion selections were modeled. Some food items were served in portions, and the others were served in individual pieces (e.g., pizza slices and strawberries; see Supplementary Table 1 for the list of portioned and piece-by-piece food items). Each portioned food item had 8 different predetermined portion sizes. Portions were established using real rice on a standard plate only for the portioned food items. These portion sizes were initially calculated by volume and were based on the amount of space the portion took up on a standard size plate. The default portion was equivalent to a single serving spoon of rice as this was the standard amount of food served by kitchen staff in the RW buffet unless a diner requested additional serving(s) of the food item.

After calculating the default serving amount for rice, we increased the size of the portion from this amount incrementally for each portion size until the plate was almost full for the largest serving size. Next, we decreased the size of the default serving incrementally for each portion amount to a little less than a teaspoon of rice for the smallest serving size. This procedure was conducted to establish the full range of volumes. Each portion of rice was scanned into the computer using photogrammetry and the volumes were precisely measured by hand. Once a digital volume was created for each portion, these volumes were filled with each portioned food item to create their respective portions. This procedure ensured, for example, that the appearance and size relative to the plate of the third portion size of fried rice would be roughly the same as the third portion size of broccoli or carrots (see Fig. 5). The middle portion size (4 of 8) was the default size presented to each participant when they first selected a food. Participants were then able to adjust the portion size with their hand-held controller by scrolling up and down to increase and decrease portion sizes, respectively.

The beverage fountain in the VR environment was modeled after a RW beverage fountain. The VR beverage fountain allowed participants

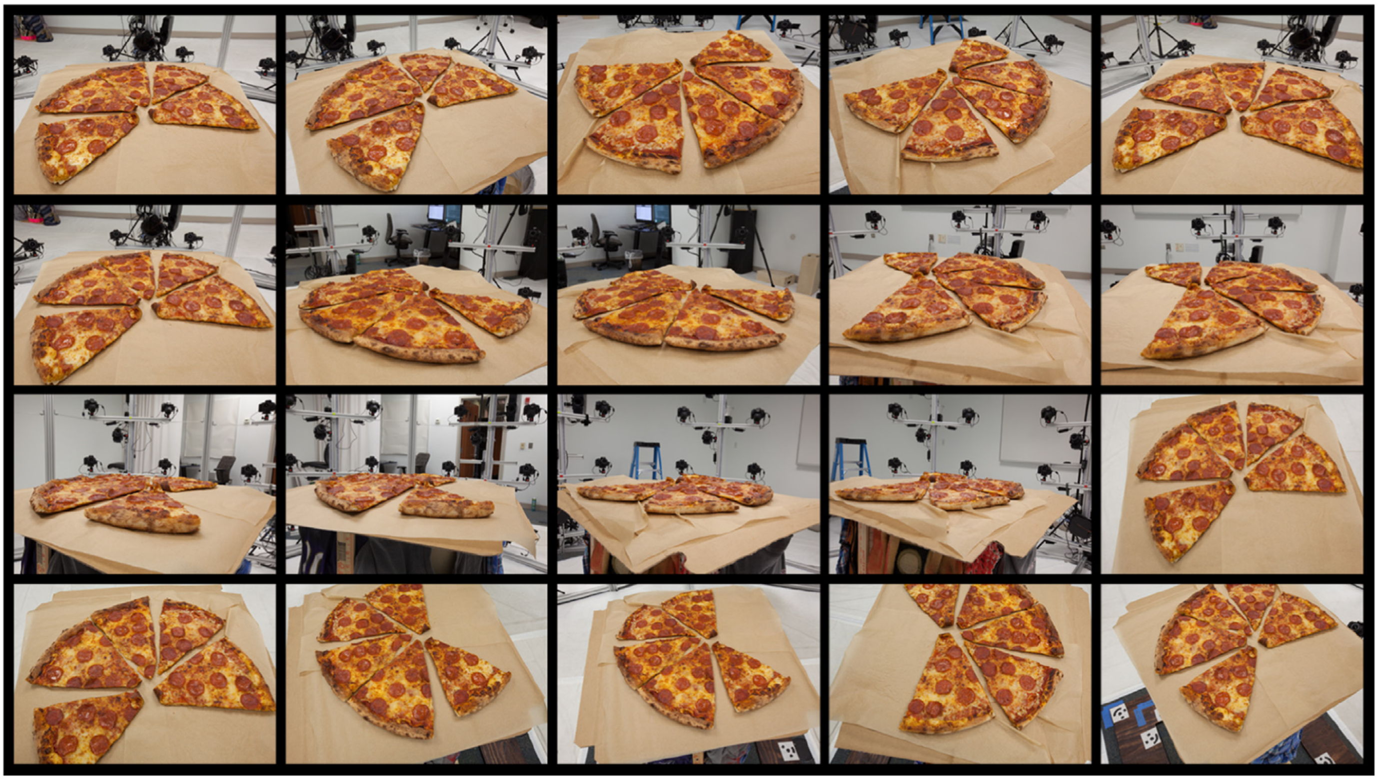

**Fig. 2.** Photogrammetry scans of pepperoni pizza.

to select drinks by holding a cup under the dispenser similar to in real life. The amount of the drink selected was determined by the length of time participants held their cup under the dispenser.

To correlate food volume to realistic weights and calorie contents, the volume measurements of each food item was obtained from the photographic and hand measured data. The volume measurement of drinks was based on the volume of a full cup in the RW buffet (451.99 mL). Each food item was then prepared for consumption and then cut or shaped to match the volume measurements of the VR food models. These prepared foods and drinks were then weighed to the nearest tenth of a gram in triplicate on a professional digital food scale (GDEALER DS1). The average of the three weight measurements was used as the approximate weight of the item (see Fig. 4). This weight was then used to calculate specific nutritional values for each food item and drink by imputing the weight and recipe of each item into the Nutrition Data System for Research (NDSR) software version 2017, developed by

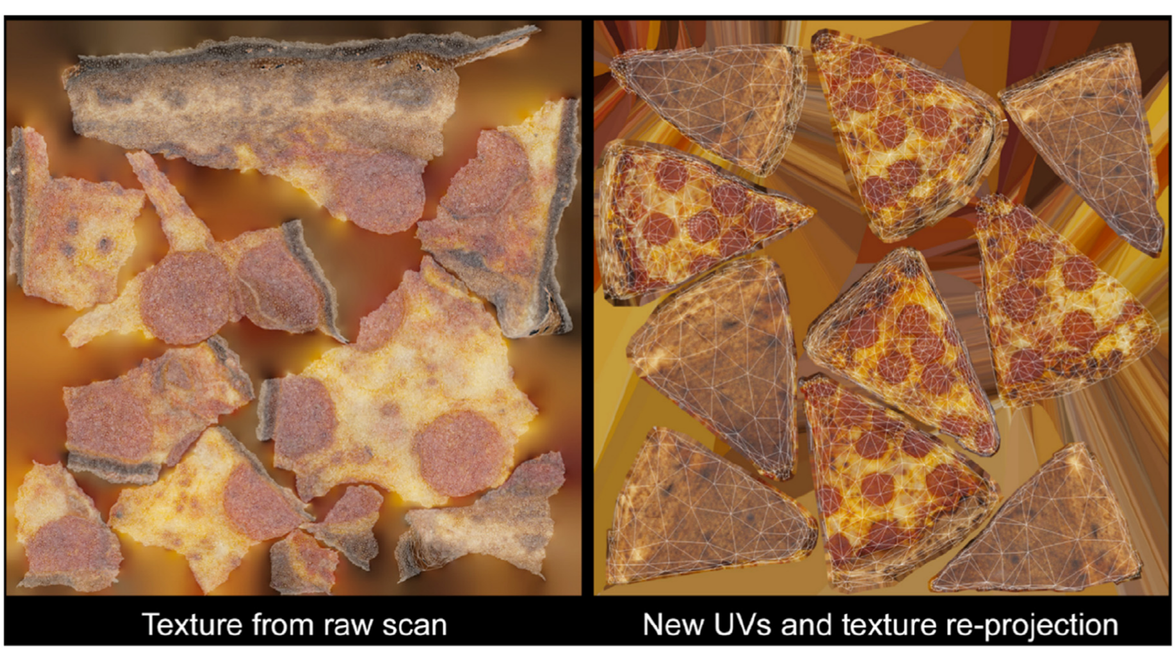


**Fig. 3.** A More Realistic Modeling of the Foods in terms of Texture and Size was Created Through Program-detection of the Same Surface Features of the Object in a Number of the Photographs.

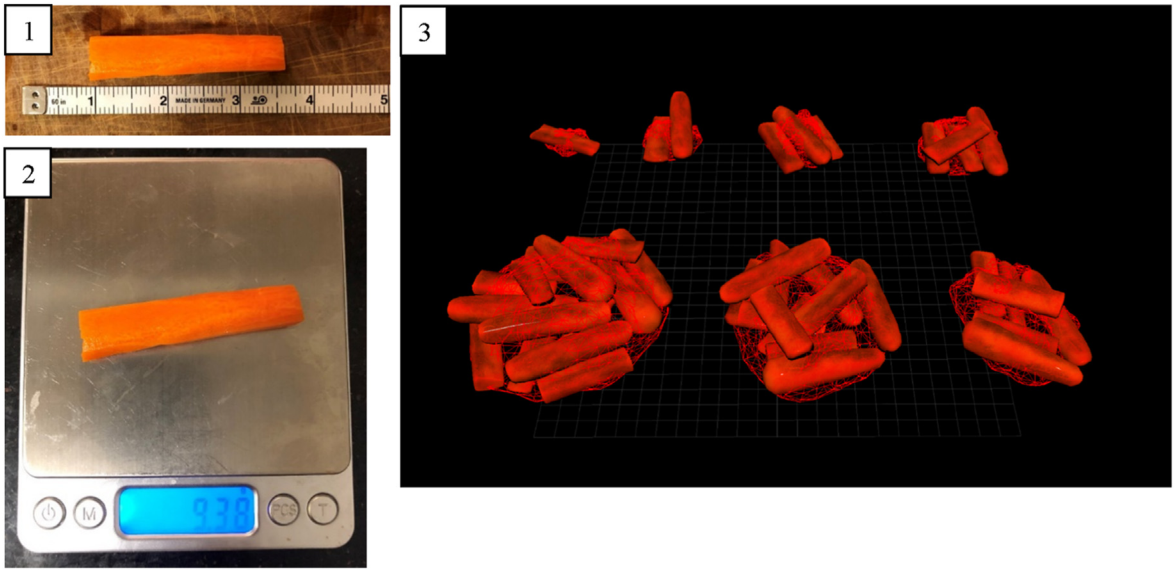


**Fig. 4.** Process to Correlate Food Volume in VR to Realistic Weights and Calorie Contents (1) Each food item (e.g., carrot as seen below): was cut or shaped to match the volume measurements of the VR food model; (2) Prepared foods were then weighed to the nearest tenth of a gram in triplicate on a professional digital food scale (GDEALER DS1); (3) This weight was then used to calculate specific nutritional values for the different portions (here, carrot portion 4 had 4 sticks) for each food item.

the Nutrition Coordinating Center at the University of Minnesota (Schakel, 2001; Schakel, Buzzard, & Gebhardt, 1997; Schakel, Sievert, & Buzzard, 1988). This process ensured that each food item's and drink's volume corresponded to an appropriate weight and subsequent caloric and nutritional estimation.

For the purposes of this study, foods with > 1.5 kcal/g were categorized as high energy density and those that were ≤1.5 kcal/g were categorized as low energy density foods similar to other studies (see Drewnowski, 2009).

Four programs, Agisoft Metashape (Version 1.3.1, 2018), Autodesk Maya (Version 2018.2, 2018), Pixologic ZBrush (Version 4R8, 2018), Adobe Substance Painter (Version 2.6.1, 2018) commonly utilized in the video game and entertainment industries were employed to model and refine each asset. All assets were then imported into the Unreal Engine (Version 4.18.3, 2018), which was used to drive the final application and render all assets to the screen.

#### 2.3.3. Real world food nutritional calculations

The nutritional value of the foods selected in RW cafeteria were calculated by having research assistants carefully separating the different foods selected by participants in the RW cafeteria buffet onto individual plates and then weighing them in triplicate on a professional digital food scale to the nearest tenth of a gram. The caloric content and nutritional information of each food item were then back-calculated using the nutritional menu data retrieved from the reported cafeteria nutritional information.

#### 2.3.4. Equipment

In the VR phase, participants wore a head-mounted virtual reality display (HTC Vive Pro). Participants used two hand-held HTC Vive controllers to pick up and put down plates, bowls, cups and foods, and change the serving amount of selected foods in the VR buffet. An advantage of the HTC Vive Pro VR system is that it tracks users' motion in 3-axes with six degrees of freedom. This feature allows users to walk/move within and interact with the VR environment naturally unlike the VR systems with three degrees of freedom motion tracking that only allow head movements and require 'teleportation' to move within the VR environment. The VR portion of this experiment was located in a large open room that allowed the participants to fully move throughout the environment such that they can walk within the VR buffet, and lean forward and reach to food items and objects to look at them and/or pick them up. Distances between counters and items were modeled to be the same in size and distance as their real-world counterparts.

#### 2.3.5. BMI measurement and calculation

To assess participants' BMI, we measured their height with a portable stadiometer (Charder HM200P) and weight with a digital weight scale (Detecto SlimPRO Low-Profile) at the beginning of the VR phase. Participants removed heavy items of clothing (e.g., jackets) and shoes for the height and weight measurements. BMI was then calculated by dividing weight in kilograms by height in meters squared ($Kg/m^2$) (Centers for Disease Control and Prevention, 2017).

### 2.4. Data analytic plan

All the hypotheses in the current study were specified before the data were collected. In addition, the analytic plan was pre-specified. All data-driven analyses were clearly identified and discussed appropriately. Descriptive analyses were conducted to examine participants' demographic characteristics, reported hunger state, and nutritional content of participants' food selections in the VR and RW buffets. To assess convergent validity, we conducted correlation analyses between the total Kcals, grams, fat, carbohydrates, and protein of participants' food selections in the VR and RW settings. Sensitivity analyses were conducted in which we computed unadjusted correlations and correlations adjusted for additional demographic variables, including BMI, hunger level, gender, and age, to assess for potential covariates. For all analyses, alpha was set at 0.05; *p*-values below .05 were statistically significant and *p*-values below .10 were considered as approaching significance. To examine the user experience in the VR environment, we assessed descriptive statistics to explore participants' self-reported perceptions of the VR buffet experience.

## 3. Results

### 3.1. Preliminary analyses

The mean rating (possible range from 0 to 100) of hunger level was 55.67 ($SD = 26.50$) in the VR phase and 55.82 ($SD = 21.48$) in the RW phase, which did not differ significantly, $t(34) = 0.08$, $p = .933$.

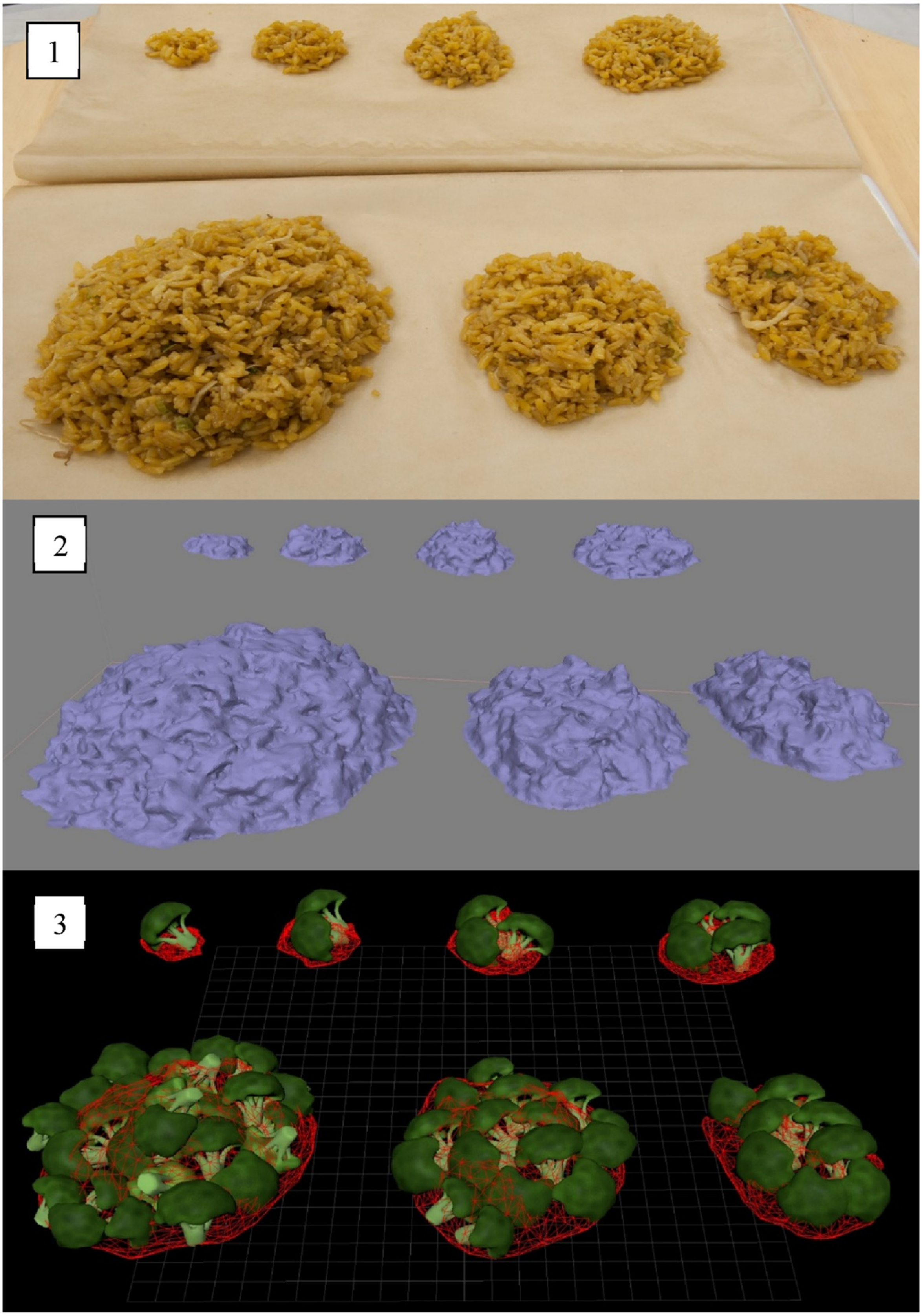


**Fig. 5.** Example of Portion Size Creation Process: 1) Universal portion volumes created from portions of rice; 2) Digitized those volumes; 3) Used the volumes to create portions for broccoli (and the other foods).

**Table 3**
Correlations between virtual reality food buffet and real-world food buffet food selections.

| Variable | Unadjusted *r* | Partial *r* controlling for Hunger State | Partial r controlling for BMI, Hunger State, Age and Gender |
|---|---|---|---|
| Total calorie selection | .60** | .58** | .59** |
| Calories from Low density food | .37* | .40* | .33†† |
| Calories from High density food | .50** | .52** | .53** |
| Total food selection in grams | .68** | .67** | .67** |
| Grams from Low density food | .54** | .57** | .53** |
| Grams from High Density food | .46** | .51** | .52** |
| Fat selection in grams | .38* | .38† | .34††† |
| Carbohydrate selection in grams | .57** | .56** | .57** |
| Protein selection in grams | .54** | .53** | .56** |

*Note.* BMI = Body Mass Index (Kg/m$^2$). Foods with > 1.5 kcal/g were categorized as high density and those that were ≤1.5 kcal/g were categorized as low-density foods. *N* = 35; **p* < .05, ***p* < .01, †*p* = .055, ††*p* = .073, †††*p* = .063.

However as individual participants' hunger level may still have varied between the two sessions and hunger levels are likely to influence responsiveness to food stimuli (Smeets et al., 2019), we chose to control for hunger in all analyses.

After controlling for participants' hunger level, the nutritional content between foods selected in VR and RW did not differ for amounts of Kcals, $F(1, 32) = 0.88$, $p = .353$; grams, $F(1, 32) = 0.20$, $p = .655$; fat, $F(1, 32) = 0.71$, $p = .406$; carbohydrates, $F(1, 32) = 0.43$, $p = .518$; and protein, $F(1, 31) = 0.45$, $p = .508$. BMI was not significantly correlated with participants' food selections in VR and RW. There were no gender differences apparent across any of the food selection variables.

### 3.2. Correlations between VR and RW buffet selections (validation)

The correlations for participants' food selection across both VR and RW sessions are presented in Table 3. All correlations were positive and significant after controlling for hunger level except for fat selection in grams, which approached significance at $p = .055$.

We also performed two sensitivity analyses by computing unadjusted correlations and correlations adjusted for additional demographic variables including BMI, hunger level, gender, and age (see Table 3). Results were similar in both sensitivity analyses with only two differences of note. When not adjusting for hunger level, the correlation of fat selection between the RW and VR sessions became significant. When adjusting for additional variables, the correlation of calories selected from low energy-dense foods between the RW and VR sessions approached significance ($p = .073$).

### 3.3. User experience

To assess user experience in the VR environment and address the second aim of the present study, we examined participants' ratings (possible range from 0 to 100) on (a) "How natural was the overall experience?"; (b) "How much did your final selection represent the lunch that you would select and eat/drink on an average day?"; and (c) "How much did your final selection represent the lunch that you would select and eat/drink if the same selection was available?" in the VR buffet environment.

Participants' ratings on the naturalness of their overall experience in the VR buffet were high ($M = 70.97$, $SD = 20.92$) and did not differ from their rating on the same question about the RW buffet environment ($M = 77.37$, $SD = 26.13$) when controlling for hunger level, $F(1, 32) = 0.84$, $p = .774$, indicating that they perceived their VR experience to be natural. Moreover, the final selections in the VR buffet were also rated as highly representative of what participants would select and eat on an average day ($M = 84.11$, $SD = 15.92$) and did not differ from their rating on the same question about the RW buffet environment ($M = 80.34$, $SD = 18.78$), $F(1, 32) = 0.03$, $p = .857$. Strikingly, participants perceived this representativeness to be higher if the exact same food selection was available ($M = 91.29$, $SD = 11.00$), which did not significantly differ from their rating on the same question about the RW buffet environment ($M = 89.29$, $SD = 15.39$), $F(1, 32) = 3.69$, $p = .064$.

We also performed two sensitivity analyses by conducting unadjusted within-subject mean comparisons and comparisons adjusted for additional demographic variables including BMI, hunger level, gender, and age. Results were similar in both sensitivity analyses such that there were no significant differences across VR and RW settings (see Supplementary Table 2).

## 4. Discussion

Given the impact that excess weight gain in early adulthood has on long-term health, a better understanding of food- and eating-related processes during emerging adulthood can ultimately inform prevention and intervention efforts to establish healthy weight-related behavioral patterns across adulthood. However, difficulty in assessing food selection and related behaviors and their associated outcomes have limited researchers' capacity to address such issues. The VR food buffet is an emerging promising tool for both the measurement and experimentation of these processes and has potential important clinical implications.

Our findings provided support for the convergent validity and usability of our VR food buffet as a tool to study food selection. The nutritional content of the foods that participants selected from the VR buffet when asked to make a lunch meal were positively correlated with those selected from the RW buffet with regard to the Kcals, grams, fat, carbohydrates, and protein. These correlations were significant even after controlling for participants' hunger state (except for fat selection in grams). Thus, the types of foods available and the nutritional content of these foods in the VR buffet appeared to simulate foods that were selected in the RW food buffets, similar to findings reported by other food choice assessment and estimation tools in the literature (Bucher et al., 2012; Bucher & Keller, 2014; Matheson, Hanson, McDonald, & Robinson, 2002; Persky et al., 2018; Ung et al., 2018).

In previous validation studies, the food selection and related behaviors in VR and RW were usually restricted to the same foods and assessed on the same day (usually within minutes) in laboratory settings (e.g., Persky et al., 2018; Ung et al., 2018). However, the positive correlations revealed in our study are particularly exciting because they indicated that the nutritional content of participants' food selection in the VR environment was highly related to that of their food selection in the RW cafeteria, and thus demonstrated convergent validity even when the foods that were available to the participants *varied across both the VR and RW* contexts *and* when the two meal selections were made one-week apart. What makes these findings even more promising is that the significant correlations held even though the foods available for selection in the RW context varied day-to-day (i.e., the menus in the RW food buffet differed everyday), and thus, from one participant to another. These findings highlight the high ecological validity of our VR buffet and that behaviors in VR environments may generalize to behaviors in RW.

We also assessed the acceptability of the VR environment through the participants' perceptions of the VR buffet. Participants generally rated their overall experience in the VR environment as natural, and not significantly different from their rating of the naturalness of the RW buffet experience. Participants also rated their final lunch selections to be highly representative of what they would select on an average day, particularly if the same foods were available, as expected. Thus, the acceptability of the VR environment was supported.

In our study, some of the food items (including entrees) in the RW cafeteria buffet were served by staff members. Thus, participants could ask for "more or less" but did not have direct control over the servings of these items. In contrast, participants selected all foods by themselves in the VR buffet and had more control over the specific serving sizes. The significant positive correlations found between the nutritional content of the meals selected despite these varying conditions further provided us with confidence in the generalizability of the meal selected in the VR buffet to RW situations.

### *4.1. Limitations, implications, and future directions*

Several limitations of both the tool and our validation study needs to be noted. First, the sample size in the present study was small and should be increased in future research to ensure greater confidence in these findings. In addition, we examined emerging adults' food-related behaviors due to the long-term weight-related behavioral patterns that arise during this critical developmental period and weight increase found among college students. However, eating- and food-related behaviors (Keel, Baxter, Heatherton, & Joiner, 2007; Vadeboncoeur et al., 2015) and the familiarity with VR environments (Benoit et al., 2015) may differ across age groups. Moreover, individuals attending university tend to differ from the larger population including regarding socioeconomic status and ethnicity (Henrich, Heine, & Norenzayan, 2010). Thus, future studies examining these questions in VR should include samples from other age groups and those not attending university.

Although the realism of both the virtual buffet environment and the 3D foods was maximized using photogrammetry and accurate references for creating architectural structures and to build detailed food models and textures, the environment currently does not include potentially important sensory cues, such as scent and haptics, which may reduce experimental realism (Persky et al., 2018). The functioning of the VR appears to be adequate without other sensory cues as indicated by the significant correlations between the two contexts and participants' perceptions of its naturalness, but the role of scent and haptic feedback should be examined in future studies. Moreover, other diners were present in the RW phase of data collection which may have introduced confounding variables, such as social experience. In addition, we did not include a measure of social desirability which may influence the final selections participants chose in VR and RW. Future studies comparing RW and VR buffets may consider including avatars in the VR environment to replicate a social presence in the RW and measure social desirability to examine or control for its effects.

Despite these limitations, our findings indicate that our VR buffet can be used to study food selection behavior among emerging adults, which can generalize to their RW behavior. In addition, the ease of manipulation of the VR buffet environment provides exciting possibilities for the experimental study of the impact of environmental cues and factors on food choices. Specifically, both psychological (e.g., body image beliefs) and social factors in the environment can be manipulated (e.g., including avatars to create a more social experience) in addition to basic sensory cues (e.g., colors, labeling and sounds) in VR. Priming experiments that examine the impact of implicit or explicit environmental cues that remind individuals of their weight or cultural background, for example, in relation to their food selection could also be conducted. Most importantly, the VR environment provides an identical experience for each user reducing variation in food presentation that may be introduced in real world settings or even laboratory studies. Additionally, future studies may be able to take advantage of movement data within the VR buffet environment to yield important information about decision making in meal selection (e.g., Yaremych et al., 2019).

Another area worth further investigation is the integration of different measurement modalities, which can allow for the identification of neurological and physiological processes that may underlie or contribute to food-related cognitions and behaviors and inform the development of programs to promote better health outcomes. For example, the use of Functional Near-Infrared Spectroscopy (fNIRS), a neuroimaging technique (Cutini, Moro, & Bisconti, 2012), to examine prefrontal cortex activity during food selection and the correlates between this brain activity and food-related decision making in real time can yield valuable information (Cheah et al., 2019). Moreover, the use of eye-tracking technology can facilitate the observation of saccadic movements (mean length and duration) and fixation (localization and duration) and measure attentional processing of food (Bucher & Keller, 2014; Wang, Cakmak, & Peng, 2018).

VR technology also has the potential to help alleviate risk factors and sub-clinical problems via prevention and intervention programs. Therefore, potential uses for our VR buffet environment may exist within clinical populations such as those with obesity or eating disorders. VR can be a cost-effective tool in both the short- and long-term as it allows practitioners greater control and manipulation over the environment and stimuli compared to traditional methods. Practitioners may be able to manipulate and adapt the virtual environment to provide immediate feedback during food selection trainings for more personalized interventions in the future.

In conclusion, our findings provide preliminary evidence that food selection in the VR environment generalize to real world food settings even without the need to match food selections precisely. Additionally, correlations between selections in the RW and VR food buffets remain significant even with a substantial time lag (1 week). The findings of this study provide further evidence regarding the utility of VR as a promising and validated tool in examining psychological and behavioral food-related processes.

## Author contributions

Cheah and Gong conceived of the study questions and design. Boot provide significant input on the study design. Barman, Vu, and Mandalapu contributed to the data and analysis tools. Zuber contributed to the creation and design of the experimental tools, and Mandalapu also contributed to the experimental and data tools. Jung contributed to analysis tools. Barman performed the data analysis. Cheah and Barman wrote the paper with significant input from Vu and Masterson. Jung contributed to the writing of one section of the paper.

## Disclosure

All authors have approved the final article.

## Funding

This work was supported by the Imaging Research Center Summer Faculty Research Fellowship from the Office of the Dean of the College of Arts, Humanities, and Social Sciences and the Office of the Vice President for Research, at UMBC.

## Declaration of competing interest

None.

## Acknowledgements

We would like to thank Dan Gao, Dymond Elliott, Philip Do, Meghan Utter, Stephen Kaputsos, and Ethan Zhu for their assistance with data collection.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2020.104741.

## Ethical statement

This work was supported by the Imaging Research Center Summer Faculty Research Fellowship from the Office of the Dean of the College of Arts, Humanities, and Social Sciences and the Office of the Vice President for Research, at the University of Maryland, Baltimore County, awarded to the first author. Ethical approval for this study was obtained from the Internal Review Board of the University of Maryland, Baltimore County (Protocol #Y19CC20012 - Understanding Healthy Development in Young Adults).

## References


Adobe (2018). *Substance painter (version 2.6.1) [computer software]*. Retrieved from https://adobe.com/.

Agisoft (2018). *Metashape (version 1.3.1) [computer software]*. Retrieved from https://www.agisoft.com/.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596.

Anderson, D. A., Shapiro, J. R., & Lundgren, J. D. (2003). The freshman year of college as a critical period for weight gain: An initial evaluation. *Eating Behaviors, 4*(4), 363–367. https://doi.org/10.1016/S1471-0153(03)00030-8.

Arnett, J. J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist, 55*(5), 469–480. https://doi.org/10.1037/0003-066X.55.5.469.

Autodesk (2018). *Maya (version 2018.2) [computer software]*. Retrieved from https://www.autodesk.com/.

Balcombe, K., Fraser, I., & Falco, S. Di (2010). Traffic lights and food choice: A choice experiment examining the relationship between nutritional food labels and price. *Food Policy, 35*(3), 211–220. https://doi.org/10.1016/j.foodpol.2009.12.005.

Benoit, M., Guerchouche, R., Petit, P. D., Chapoulie, E., Manera, V., Chaurasia, G., et al. (2015). Is it possible to use highly realistic virtual reality in the elderly? A feasibility study with image-based rendering. *Neuropsychiatric Disease and Treatment, 11*, 557–563. https://doi.org/10.2147/NDT.S73179.

Bucher, T., & Keller, C. (2014). The web-buffet – development and validation of an online tool to measure food choice. *Public Health Nutrition, 18*(11), 1950–1959. https://doi.org/10.1017/S1368980014002456.

Bucher, T., van der Horst, K., & Siegrist, M. (2012). The fake food buffet – a new method in nutrition behaviour research. *British Journal of Nutrition, 107*(10), 1553–1560. https://doi.org/10.1017/S000711451100465X.

Centers for Disease Control and Prevention. (2017). *About adult BMI*. Retrieved January 11, 2020, from https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html.

Cheah, C. S. L., Kaputsos, S. P., Mandalapu, V., Tran, T., Barman, S., Jung, S. E., ... Gong, J. (2019). Neurophysiological variations in food decision-making within virtual and real environments. *2019 IEEE EMBS international conference on biomedical & health informatics (BHI)*https://doi.org/10.1109/BHI.2019.8834497 1–4.

Crombie, A. P., Ilich, J. Z., Dutton, G. R., Panton, L. B., & Abood, D. A. (2009). The freshman weight gain phenomenon revisited. *Nutrition Reviews, 67*(2), 83–94. https://doi.org/10.1111/j.1753-4887.2008.00143.x.

Cutini, S., Moro, S. B., & Bisconti, S. (2012). Functional near infrared optical imaging in cognitive Neuroscience: An introductory review. *Journal of Near Infrared Spectroscopy, 20*(1), 75–92. https://doi.org/10.1255/jnirs.969.

Drewnowski, A. (2009). Energy density, Palatability, and Satiety: Implications for weight control. *Nutrition Reviews, 56*(12), 347–353. https://doi.org/10.1111/j.1753-4887.1998.tb01677.x.

Fernandes, A. C., Oliveira, R. C., Proença, R. P. C., Curioni, C. C., Rodrigues, V. M., & Fiates, G. M. R. (2016). Influence of menu labeling on food choices in real-life settings: A systematic review. *Nutrition Reviews, 74*(8), 534–548. https://doi.org/10.1093/nutrit/nuw013.

Fisher, J. O., & Birch, L. L. (1999). Restricting access to palatable foods affects children's behavioral response, food selection, and intake. *American Journal of Clinical Nutrition, 69*(6), 1264–1272. https://doi.org/10.1093/ajcn/69.6.1264.

Forman, E. M., Goldstein, S. P., Flack, D., Evans, B. C., Manasse, S. M., & Dochat, C. (2018). Promising technological innovations in cognitive training to treat eating-related behavior. *Appetite, 124*, 68–77. https://doi.org/10.1016/j.appet.2017.04.011.

Epic Games (2018). *Unreal engine (version 4.18.3) [computer software]*. Retrieved from https://www.unrealengine.com.

Gordon-Larsen, P., Adair, L. S., Nelson, M. C., & Popkin, B. M. (2004). Five-year obesity incidence in the transition period between adolescence and adulthood: The National longitudinal study of Adolescent health. *American Journal of Clinical Nutrition, 80*(3), 569–575. https://doi.org/10.1093/ajcn/80.3.569.

Gorini, A., Griez, E., Petrova, A., & Riva, G. (2010). Assessment of the emotional responses produced by exposure to real food, virtual food and photographs of food in patients affected by eating disorders. *Annals of General Psychiatry, 9*(1), 30. https://doi.org/10.1186/1744-859X-9-30.

Gutiérrez-Maldonado, J., Wiederhold, B. K., & Riva, G. (2016). Future Directions: How virtual reality can further improve the assessment and Treatment of eating disorders and obesity. *Cyberpsychology, Behavior, and Social Networking, 19*(2), 148–153. https://doi.org/10.1089/cyber.2015.0412.

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences, 33*, 61–83. https://doi.org/10.1017/S0140525X0999152X.

Keel, P. K., Baxter, M. G., Heatherton, T. F., & Joiner, T. E. (2007). A 20-year longitudinal study of body weight, dieting, and eating disorder symptoms. *Journal of Abnormal Psychology, 116*(2), 422–432. https://doi.org/10.1037/0021-843X.116.2.422.

Marcum, C. S., Goldring, M. R., McBride, C. M., & Persky, S. (2018). Modeling Dynamic food choice processes to understand Dietary intervention effects. *Annals of Behavioral Medicine, 52*(3), 252–261. https://doi.org/10.1093/abm/kax041.

Matheson, D. M., Hanson, K. A., McDonald, T. E., & Robinson, T. N. (2002). Validity of children's food portion Estimates. *Archives of Pediatrics and Adolescent Medicine, 156*(9), 867. https://doi.org/10.1001/archpedi.156.9.867.

Nelson, M. C., Story, M., Larson, N. I., Neumark-Sztainer, D., & Lytle, L. A. (2008). Emerging adulthood and college-aged Youth: An Overlooked age for weight-related behavior change. *Obesity, 16*(10), 2205–2211. https://doi.org/10.1038/oby.2008.365.

Park, M. J., Paul Mulye, T., Adams, S. H., Brindis, C. D., & Irwin, C. E. (2006). The health status of young adults in the United States. *Journal of Adolescent Health, 39*(3), 305–317. https://doi.org/10.1016/j.jadohealth.2006.04.017.

Parsons, T. D., & Rizzo, A. A. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry, 39*(3), 250–261. https://doi.org/10.1016/j.jbtep.2007.07.007.

Persky, S., Ferrer, R. A., Klein, W. M. P., Goldring, M. R., Cohen, R. W., Kistler, W. D., ... Bouhlal, S. (2019). Effects of Fruit and Vegetable feeding messages on Mothers and Fathers: Interactions between emotional state and health message Framing. *Annals of Behavioral Medicine, 53*(9), 789–800. https://doi.org/10.1093/abm/kay088.

Persky, S., Goldring, M. R., Turner, S. A., Cohen, R. W., & Kistler, W. D. (2018). Validity of assessing child feeding with virtual reality. *Appetite, 123*, 201–207. https://doi.org/10.1016/j.appet.2017.12.007.

Peschel, A. O., Orquin, J. L., & Mueller Loose, S. (2019). Increasing consumers' attention capture and food choice through bottom-up effects. *Appetite, 132*, 1–7. https://doi.org/10.1016/j.appet.2018.09.015.

Pixologic (2018). *ZBrush (version 4R8) [computer software]*. Retrieved from https://pixologic.com/.

Racette, S. B., Deusinger, S. S., Strube, M. J., Highstein, G. R., & Deusinger, R. H. (2008). Changes in weight and health behaviors from freshman through Senior Year of college. *Journal of Nutrition Education and Behavior, 40*(1), 39–42. https://doi.org/10.1016/J.JNEB.2007.01.001.

Schakel, S. F. (2001). Maintaining a nutrient database in a changing Marketplace: Keeping Pace with changing food Products—a research Perspective. *Journal of Food Composition and Analysis, 14*(3), 315–322. https://doi.org/10.1006/jfca.2001.0992.

Schakel, S. F., Buzzard, I. M., & Gebhardt, S. E. (1997). Procedures for estimating nutrient values for food Composition Databases. *Journal of Food Composition and Analysis, 10*(2), 102–114. https://doi.org/10.1006/jfca.1997.0527.

Schakel, S. F., Sievert, Y. A., & Buzzard, I. M. (1988). Sources of data for developing and maintaining a nutrient database. *Journal of the American Dietetic Association, 88*(10), 1268–1271. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3171020.

Smeets, P. A. M., Dagher, A., Hare, T. A., Kullmann, S., van der Laan, L. N., Poldrack, R. A., ... Veldhuizen, M. G. (2019). Good practice in food-related neuroimaging. *American Journal of Clinical Nutrition, 109*(3), 491–503. https://doi.org/10.1093/ajcn/nqy344.

Sussman, S., & Arnett, J. J. (2014). Emerging adulthood: Developmental period facilitative of the Addictions. *Evaluation & the Health Professions, 37*(2), 147–155. https://doi.org/10.1177/0163278714521812.

Ung, C.-Y., Menozzi, M., Hartmann, C., & Siegrist, M. (2018). Innovations in consumer research: The virtual food buffet. *Food Quality and Preference, 63*, 12–17. https://doi.org/10.1016/j.foodqual.2017.07.007.

Vadeboncoeur, C., Townsend, N., & Foster, C. (2015). A meta-analysis of weight gain in first year university students: Is freshman 15 a myth? *BMC Obesity, 2*(1), 22. https://doi.org/10.1186/s40608-015-0051-7.

Vella-Zarb, R. A., & Elgar, F. J. (2009). The 'freshman 5': A meta-analysis of weight gain in the freshman Year of college. *Journal of American College Health, 58*(2), 161–166. https://doi.org/10.1080/07448480903221392.

Wang, E., Cakmak, Y. O., & Peng, M. (2018). Eating with eyes – comparing eye movements and food choices between overweight and lean individuals in a real-life buffet setting. *Appetite, 125*, 152–159. https://doi.org/10.1016/j.appet.2018.02.003.

Yaremych, H. E., Kistler, W. D., Trivedi, N., & Persky, S. (2019). Path Tortuosity in virtual reality: A Novel Approach for Quantifying behavioral process in a food choice context. *Cyberpsychology, Behavior, and Social Networking, 22*(7), 486–493. https://doi.org/10.1089/cyber.2018.0644.

Zellner, D. A., Loaiza, S., Gonzalez, Z., Pita, J., Morales, J., Pecora, D., et al. (2006). Food selection changes under stress. *Physiology & Behavior, 87*(4), 789–793. https://doi.org/10.1016/j.physbeh.2006.01.014.