Eating together while being apart: A pilot study on the effects of mixed-reality conversations and virtual environments on older eaters' solitary meal experience and food intake

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ABSTRACT

The aim of this study was to investigate the potential of mixed-reality systems to virtually manipulate the eating experience and facilitate increased food intake among older participants. Social isolation is often associated with undernourishment among older adults receiving care services. Mixed-reality systems that blend real elements and a virtual world can conveniently allow older adults to eat a meal in their home while experiencing having a conversation with friends through virtual avatars in a virtual environment. A within-subjects study on thirty older participants investigated whether the mixed-reality illusion of eating in a living room with and without familiar others contributed positively to the meal experience and increased energy intake. The results did not display any significant changes in energy intake but highlighted that the virtual living room had a more energetic and pleasant atmosphere and that meals eaten in the virtual room were perceived to be of a higher quality compared to meals eaten in the real lab environment. Eating while engaging in avatar-based social interactions with three remotely located friends resulted in lower sensations of being alone and positive mood changes. A discussion of the reasons for the absence of increases in energy intake is included.

Index Terms: Information systems—Information systems applications—Collaborative and social computing systems and tools; Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality

1 INTRODUCTION

An increase in life expectancy in combination with a decline in fertility rates is globally making older adults a larger part of the population [40]. The growth in this population group will result in increased health care expenditures and make it beneficial to keep the older segment healthy and functional [11]. Insufficient nutrition over longer periods of time has been linked to increased risk of morbidity, mortality, and functional disability among older adults' [25]. Investigations of risk factors have found that at least one out of ten home-living older adults in Northern Europe are malnourished and that undernourishment is even more common among older adults who are hospitalized or receive care services [3, 30].

One of the correlating factors to malnutrition in older people is social isolation [6]. Regular contact with others may result in adherence to societal dietary norms and affect food intake through improved mood and self-esteem, and perceived support [41]. Previous studies on older participants have shown a strong correlation between social interactions while eating and an increase in food intake [28, 32]. This effect has been called *social facilitation of eating* and describes the increase in food intake observed under certain circumstances in a restricted group of co-eaters [13]. It has been expressed as the most powerful stimuli that affect the ad libitum intake of humans [7] and several theories have been proposed to explain the effect. These include extension of the eating session and thus increased exposure to food cues [33], using occasions of social eating as an excuse to overindulge [13], social conversations as distraction which lowers self regulation [17], and the absence of reasons to stop eating [16]. Individuals might eat less to express femininity, self-control, or politeness to another person (called impression management), or be influenced by cues from others that signal the appropriate amount of food to eat during a meal (called modelling) [13]. An eater might perceive meal partners as eating more than him or her and thus modelling will make the eater increase food intake to mirror the perceived intake of the meal partner [14].

However, the opportunities for sharing a meal might diminish with old age due to concerns about intrusion into others' lives, disability, loss of loved ones, living and eating alone [38]. The time already reserved for a meal could potentially be shared by using technology to facilitate enjoyable meal conversations between the older adults and their family or friends. Social media allow virtual social events to be experienced through head-mounted displays (HMDs), where the older adults can talk and interact with each other virtually through avatars [31]. Mixed reality (MR) HMDs [23] combine a virtual environment (VE) and real elements (e.g., hands and food), and can allow the user to handle and eat real food items while being engaged in virtual conversations. Thus, such systems could potentially be deployed in a domestic or hospital setting to facilitate stimulating virtual meals as a strategy for coping with solitary meals [20].

Because MR systems are able to present a virtual eating environment to the user, it is interesting that the environment in which a meal is consumed has also been reported to affect food intake [21], as well as perceived palatability [29], and choice of food [27]. We refer to an increase in food intake as a result of the environment by the term *environmental facilitation of eating*. In particular, restaurants have been found to increase food intake [9]. Following the thought behind the inhibitory model [16], eating in an environment with a pleasant atmosphere might indirectly lead to increased consumption because the environment introduces fewer reasons to stop eating. The immersive capabilities of HMDs can create an illusion that makes the user experience "being there" in the VE (often referred to as the sensation of *presence*) [35]. Established presence in VEs has been found to increase the ecological validity of tasting booths [2] and make the users react similarly to how they would in a real environment [1].

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Several audio-/video-based installations have demonstrated a positive effect of virtual meals between remotely located eaters, such as reduce loneliness [39], and increased appetite, motivation to eat, meal satisfaction, and improved mood [19]. MR systems using HMDs distinguish themselves from the audio-/video-based setups with an increased level of immersion by providing the user with an increased field of view and stereoscopic visuals updated with head-tracking, all of which are powerful promoters of presence [8]. MR systems thus create the illusion of being placed in the environment rather than observing it through a window. No studies have to our knowledge investigated the effects of social MR systems on aspects of the meal experience.

The objective of this study was to investigate whether environmental and social facilitation of eating can be achieved among isolated eaters by augmenting their meal experience through the use social MR systems. This was done by comparing the food intake and self-rated meal experience of older adults in three scenarios: a baseline meal eaten in our lab setting (no MR), a meal eaten alone while experiencing a VE (alone MR), and a meal eaten alone while engaging in avatar-based social interaction with two friends in a shared VE (social MR).

2 METHOD

2.1 Participants

The participants were purposely recruited outside the intended target group for the proposed MR systems. This was due to ethical considerations of exposing malnourished older adults to a study that attempts to identify the effects of potentially nausea-inducing immersive MR systems [26]. It was therefore decided to use participants who were sufficiently nourished and functional but who still could experience the effects of age on the meal experience [25]. Thirty older Danes (age M = 71.23 SD = 4.23) recruited through the Consumer Panel at Copenhagen University participated in the experiment. Females were overrepresented in the sample; twice as many females as male participated. The inclusion criteria were an age of 65 years or above, living at home, and being able to transport oneself to the lab with two friends of the same age. The exclusion criteria were major cognitive disabilities, eating or physical impairments that disallowed the participant to eat from a low seat and if any major technical errors occurred during their virtual meals. All participants gave informed consent. A voucher of 450 DKK was given for participation.

2.2 Study design

A counterbalanced within subject (repeated measures) experiment was performed. The independent variable in the experiment was the context of eating; we instructed participants to eat during three conditions: (no MR) eating alone in a real environment, (alone MR) eating alone in mixed reality, and (social MR) eating together in mixed reality, with virtual avatar representations of friends. The dependent variables were energy intake (kJ) during each condition and the participants' subjective rating of the meal experience.

2.3 Measurements

The served food and beverages were weighed before and after the meal session. The weight difference was used to calculate the energy intake of the consumed food and beverages by consulting the nutrition labelling on the served items. To measure the meal experience, a short questionnaire was filled out by each participant before and after an eating session. Table 1 provides an overview of the Likert items included in the questionnaire and whether the items were filled out before and/or after the meal session. The questionnaire attempted to measure the meal experience through three aspects: internal factors, food-related factors, and environmental factors [10].

Hunger and fullness were measured using an item corresponding to the boundary model (seven options) [15]; the rest of the items in the questionnaire were rated using five options. The circumplex model of affect [34] was used to rate mood and atmosphere by valance and arousal, but the arousal scale was adapted to describe the energy experienced as part of the atmosphere in a room, rather than that of an internal bodily state [24]. Items adopted from the meal assessment tool (MAT) questionnaire were used to measure the food-related factors [12]. In the alone MR and social MR conditions,

Constructs	Questions
Internal Hunger (before and after)	How do you feel at this moment? "Starved" (1); "Stuffed" (7) How great is your desire to eat at this moment? "No desire" (1); "Extremely strong desire" (5)
Internal Mood (before and after)	How would you rate your mood at this moment? "Very negative" (1); "Very positive" (5) "Very quiet" (1); "Very unquiet" (5)
Food Perception (after)	How would you rate the food you have just eaten? Taste: "Very poor" (1); "Very good" (5) Appearance with HMD: "Very poor" (1); "Very good" (5)[†] Appearance without HMD: "Very poor" (1); "Very good" (5)[†] Quality: "Very poor" (1); "Very good" (5) How did you experience the buffet offered? "Nothing that I wanted to eat" (1); "I wanted to eat from all the foods" (5) How satisfied are you with the meal you just had? "Very dissatisfied" (1); "Very satisfied" (5) How difficult was it to eat the food? "Very difficult" (1); "Very easy" (5)
Environment Perception (after)	How would you rate your perception of being in the living room environment?[‡] "No perception of being in the environment" (1); "Completely as being in the environment" (5) How suitable was the environment for eating the served food? "Very unsuitable" (1); "Very suitable" (5) How did you perceive the atmosphere of the environment? "Very unpleasant" (1); "Very pleasant" (5) "Very quiet" (1); "Very energetic" (5)
Social Environment (after)	*All items answered with five options: "Disagree" (1) to "Agree" (5)* I often felt as if I were all alone I often felt as if I were having a natural conversation[§] I had a real sense of personal contact with my meal partners[§] I often felt completely absorbed in the conversation[§] I enjoyed the conversation with my meal partners[§]

[†] The two questions were replaced by one question labelled "Appearance" instead of "Appearance with HMD" and "Appearance without HMD" in the questionnaire given to participants after eating in a real environment.
[‡] Not included in the questionnaire given to participants after eating in a real environment.
[§] The questions were only given after the social MR condition.

Table 1: Meal experience questions answered by the participants before and/or after the eating session

the item asking about the appearance of the meal was replaced by two items asking about the appearance with and without wearing the HMD. A difficulty-item was added, because we expected that the HMD might hinder access to the food [22]. In the alone MR and social MR conditions, an item from the Slater-Usoh-Steed (SUS) presence questionnaire was added, asking about the sense of being in the VE [36]. A loneliness-item was included in the questionnaire given after all conditions and extra questions regarding the social interactions in the social MR condition were included.

2.4 Setup

Cakes were chosen as food items for the experiment because they can be eaten by hand and may in Danish culture accompany coffee during forenoon and afternoon breaks. The cakes were served in small snack sizes to avoid introducing an artificial intake limit from a single item because some participants might stop after one piece of cake. The same cake buffet was offered the participants during each condition. The buffet consisted of 10 mini muffins (1726.5 kJ/100g), 10 coconut cakes (Royal Kokosstjerner 1910 kJ/100g), 16 cut pieces of mazarine cake (Royal Mini mazariner 1730 kJ/100g), and 16 apple boats (Pink lady 226 kJ/100g) dipped in pineapple juice to delay them from turning brown. Instead of hazardous hot coffee, three types of boxed juice were offered with the cake buffet: apple juice (Vitafit 177 kJ/100ml), orange juice (Vitafit 186 kJ/100ml), and multi juice (Vitafit 196 kJ/100ml).

The experiment used three eating stations to immerse the participants in MR (see Figure 1). The eating stations were located in separate rooms, completely isolating the participants from each other. A microphone was located in each room allowing the researcher to react to calls for assistance. Each eating station consisted of an eating interface mounted to a Oculus Rift CV1 HMD connected to a VR-compatible PC. The eating interface was developed by Korsgaard et al. and made it possible for the participant to see his/her own hands and interact with food on the table (see Figure 2) [22]. The chosen VE was a living room with a fireplace in an apartment[1] in which the participants would be sitting on couches and eating from a table in the center. The location was chosen because it had a realistic style preferred by older adults and was appropriate for the served cakes [22]. Friends appeared in the mixed reality as instances of the same semitransparent white genderless avatar (see Figure 2) to avoid possible bias introduced by customised looks. The avatars and network code were implemented using Oculus Platform and Avatar SDK. The meal partners were able to hear each other due to a microphone built into the HMD. The rotation and translation of the HMD was also mapped to the avatar, enabling the meal partners to see when and how the participant moved his or her head. However, meal partners were not able to see the food in front of the participant, nor the participant's hands. This was not displayed to the meal partners due to limitations associated with the method for creating the virtual food and limbs.

2.5 Procedure

The experiment was performed between March and May 2018. Three appointments were scheduled with the participant, at which he or she ate at the buffet while experiencing one of the three conditions. All three appointments for the same participant were consistently either in the forenoon (10:00 to 11:30 AM) or in the afternoon (01:30 to 03:00 PM). Each of the three appointments was scheduled a minimum of 48 hours apart and 21 days were the maximum time a participant used to complete all three appointments.

On the first appointment, the participant was told that we would measure the meal experience during the three appointments, and asked to report any lifestyle changes during the period. The participant's age and phone number were recorded, the latter to send out reminders the day before an appointment. The participant was also assigned one of the tree eating stations to ensure that the participant sat in the same room during each appointment. The participant was asked to fast two hours before each appointment and follow his or her regular dietary pattern as closely as possible. The participant was then seated at the eating station, with the buffet ready and visible on the table. The before-questionnaire was filled out by the participant on a tablet. The participant was (in the mixed-reality and social mixed-reality condition instructed on how to use the head-tracked HMD, then) told to eat as much or as little as he or she liked until he or she felt comfortably full. To end the meal, the participant was instructed to say the name of the room out loud (the rooms were given names to distinguish them) because the microphone would enable an assistant to hear and react. After the eating session, the participant was given the version of the after-questionnaire that corresponded with the condition just received. The participant was then reminded of the time of the next appointment (if any) and kindly shown to the door.

[1]Asset package from Unity AssetStore named "ArchVizPRO Interior Vol.3" by ArchVizPRO

Figure 1: One of the eating stations as viewed before an appointment.

Figure 2: The avatars, the environment, the food and hands of the user as viewed from inside the HMD.

2.6 Data analysis

The three sample distributions of energy intake and meal duration were investigated for significant differences using parametric repeated measures ANOVAs. The Likert items in the questionnaire were treated as ordinal data [42]. Monotonical relationships were investigated using Spearman's rank correlation coefficient, and Friedman's rank test was used to test for significance. For post hoc testing, the Wilcoxon-Nemenyi-McDonald-Thompson approach was

used [18]. In cases where a measurement was taken before and after the meal session (Internal Hunger and Mood) a cumulative link mixed model was fitted to the data with the adaptive Gauss-Hermite quadrature approximation using 10 quadrature points. The after level was modelled with before level and condition as fixed effects, while a random subject effect was used to account for repeated measures. The significance of the condition was investigated using likelihood ratio tests between the full model and a model without the condition effect. Post hoc analysis was performed using least square means with Tukey comparisons. The analysis was performed using RStudio. In all cases, statistical significance was set to an alpha value of 0.05.

3 Results

Visualized distributions across conditions mark conditions with distinct symbols ($\star$ and $*$) if the ratings differed significantly from each other.

3.1 Energy intake and meal duration

Unexpectedly, only insignificant differences [$F = 0.535$, $p = 0.588$] were found in energy intake across conditions (social MR: $M = 1998.8$, $SD = 1093.0$ kJ; alone MR: $M = 2133.2$, $SD = 1040.1$ kJ; no MR: $M = 2136.6$, $SD = 1239.9$ kJ). Dividing the energy intake into the two categories, food and beverage, did not result in significant changes in how much were eaten or drunk across conditions, and the same was the case when energy intake was divided into distinct food and beverage items. Similar to energy intake, no significant differences [$F = 0.817$, $p = 0.445$] were observed in meal duration across conditions (social MR: $M = 811.2$, $SD = 307.7$ s; alone MR: $M = 745.9$, $SD = 427.1$ s; no MR: $M = 675.0$, $SD = 315.5$ s).

3.2 Internal state

No significant differences were found in hunger-satiated levels [$p = 0.418$], arousal levels [$p = 0.787$], or desire for the food [$p = 0.407$] across conditions. However, modelling the after-valence component of mood as a function of condition and before-valence did show a significant effect of the condition [$p < 0.05$]. The post hoc test showed that the social MR condition was significantly different from the no MR condition [$p < 0.05$] and borderline significantly different from the alone MR condition [$p = 0.052$]. Figure 3 shows that when the participants ate in a social context their mood either remained the same or became more positive.

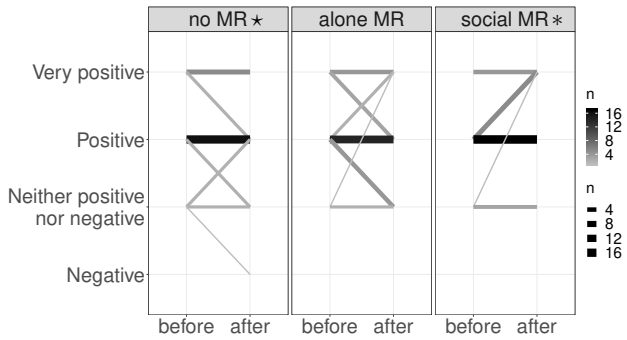

Figure 3: Aggregated valence ratings given before and after each condition to the question "How would you rate your mood at this moment?" Lines indicate the direction of change in the ratings from before to after the condition and thickness and color of the lines indicate amount of participants with the same development in ratings.

3.3 Food perception

The ratings of the appearance of the food through the HMD (in the alone MR and social MR conditions) were compared with the ratings of the appearance of the food without the HMD (in the no MR condition). Here, a significant difference was detected [$p < 0.01$]. The post hoc tests identified the appearance of the no MR baseline condition as significantly superior to both MR conditions [$p < 0.01$ and $p < 0.01$] (Figure 4). A significant effect was found in relation to the rated food quality [$p < 0.01$]. In both MR conditions the food was rated as being of a significantly higher quality compared to eating alone without MR [$p < 0.01$ and $p < 0.01$] conditions compared to eating alone without MR (Figure 4). Ratings of quality generally appeared to have a monotonical relationship with taste ratings [$rho = 0.730$, $p < 0.01$] and little dependency on the rated appearance of the food [$rho = 0.121$, $p = 0.256$]. Even though ratings of food quality and taste co-varied similarly across conditions, taste ratings only reached borderline significance levels [$p = 0.067$]. No significant effects were found in the levels of perceived food variation [$p = 0.696$] and meal satisfaction [$p = 0.823$]. The difficulty of eating the food while wearing the headset was also negligible because more than 70% rated the eating as being either "easy" or "very easy" in all conditions, and no significant differences were found [$p = 0.915$].

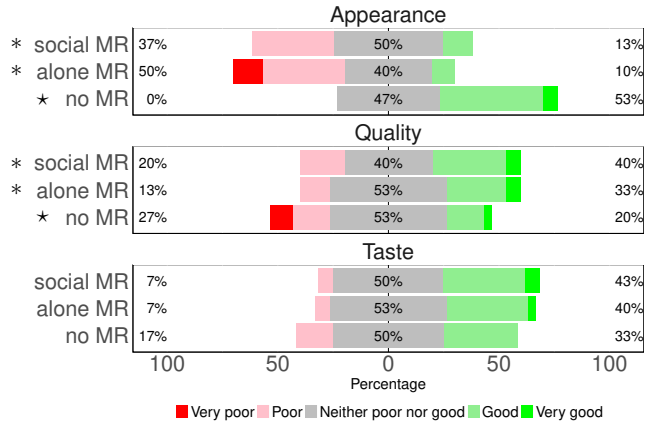

Figure 4: Distributions of the participants' ratings of the MAT items across conditions.

3.4 Environment perception

The sense of being in the virtual living room was rated as "strong feeling of being in the environment" or "completely as being in the environment" by 60% of the participants after the alone MR condition and 73% of the participants after the social MR condition with no significant difference [$p = 0.246$]. The VE was rated as a better match to the served cakes [$p < 0.01$] with post hocs showing that both MR conditions were rated significantly different from the no MR condition [$p < 0.01$ and $p < 0.01$]. The atmosphere of the real lab environment was perceived as a quiet location (Figure 5). The MR conditions made the atmosphere more energetic [$p < 0.01$], but the post hocs revealed that the alone MR condition barely reached significance in relation to the no MR condition [$p = 0.043$]. The perceived valence of the atmosphere was mostly rated as neutral in the real lab environment, while the majority rated the virtual living room environment as having a "pleasant" or "very pleasant" atmosphere (Figure 6). Both MR conditions were significantly different from the no MR condition [$p < 0.01$].

3.5 Social environment

When comparing the self-rated loneliness across treatment [$p < 0.01$], participants reported to feel significantly more lonely during the no MR and alone MR conditions compared to the social MR condition [$p < 0.01$] (Figure 7). From the self-rated measurements only recorded in the social MR condition (Figure 8), the majority the participants agreed or partly agreed with the statements.

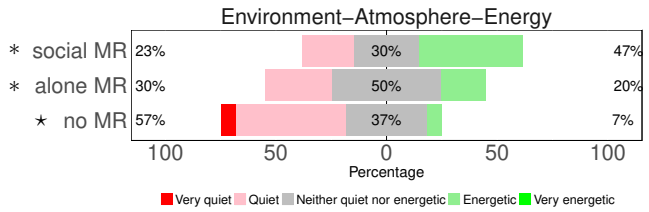

Figure 5: Distribution of the participants' ratings in each condition to the question "How did you perceive the atmosphere of the environment?"

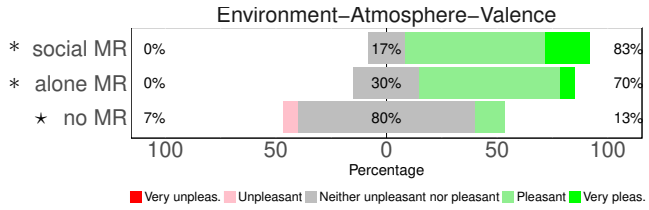

Figure 6: Distribution of the participants' ratings in each condition to the question "How did you perceive the atmosphere of the environment?"

The item asking about complete absorption in the conversion, breaks the pattern as 17% partly disagreed, 33% remained undecided and only 17% fully agreed with the statement.

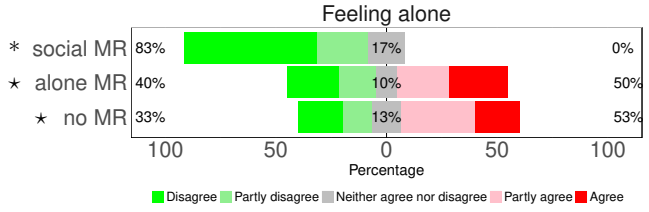

Figure 7: Distribution of the participants' ratings in each condition to the statement "I often felt as if I was all alone."

4 Discussion

Surprisingly, no significant differences were found in energy intake across conditions, thus this study falls in the category of studies that failed to find the social facilitation effect [5]. Notably, only two participants ate to a point at which they felt over-satiated (stuffed), indicating that most participants were in control of their intake or found reasons to stop prematurely. Absorption in the conversation were rated the lowest among the items measuring conversation quality. Having participants arrive in a group with their friends might be a bias in the experimental design as this gave them the opportunity to chat before and after the social condition. This opportunity may have exhausted conversation topics before the social condition, leaving little motivation to make conversation during the MR experience after the initial novelty has faded. In addition, the missing feature of being able to see the food of meal partners might have influenced the food consumption. The participants might have compensated with verbal cues instead of the missing visual cues [37], making the awareness of food consumption unnaturally high. Another limitation may be the choice of food as the pleasant and distracting stimuli from the social MR condition might not have been enough to mask the guilt of eating cakes or desserts, which are often considered something to eat in moderation. Finally, the microphone in the rooms to call for help may have introduced a bias as it is known that non-eating observers can have a negative effect on an eaters intake [13]. Adding

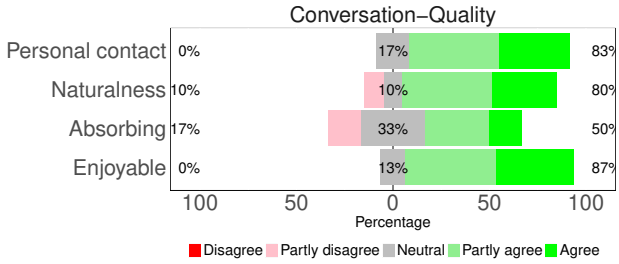

Figure 8: Distribution of the participants' ratings in response to the statements "I enjoyed the conversation with my meal partners," "I often felt completely absorbed in the conversation," "I often felt as if I was having a natural conversation," and "I had a real sense of personal contact with my meal partners."

a non-virtual social condition to the experimental design could have helped in uncovering these biases as the absence of increased energy intake in the new condition would exclude the MR system as an explaining factor.

Looking at the results from a positive perspective, it is a promising starting point for MR-based eating systems that wearing the device did not lower the amount of food consumed during eating sessions. The VE itself was rated as having a pleasant and more energetic atmosphere and being more appropriate for the served cakes compared to the real lab environment. The VE made the participants rate the food as being of a higher quality, and they had a tendency to rate it as better tasting. The VE's ability to positively influence how the participants experienced the food might be explained by a halo effect, where the positive evaluation of the environment positively contributed to the evaluation of the food, as good food is usually served in fine surroundings. In previous studies, the eating environment has been found to alter the perceived ethnicity [4] and acceptability [10, 29] of food. These findings add to the literature showing that a virtual eating environment has an impact on how the food is experienced and the ecological validity of immersive technologies [1, 2]. Half of the participants felt alone when eating in the VE without virtual others, but none of the participants indicated that they felt alone during the social condition. Thus, it appears that avatar-based communication (similar to audio-/video-based systems [19, 39]) also has the ability to ease loneliness. However, it should be noted that many of the older adults who participated in the experiment had never worn an HMD or experienced MR. As such, the positive effects attributed to the MR conditions might instead have been a result of the novelty of the experience of using MR and might diminish with extensive usage. More long-perspective studies should examine the longevity effects of social MR meals and applicability in the home and in hospitals.

Acknowledgments

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