“You Better Eat to Survive”: Exploring Cooperative Eating in Virtual Reality Games

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ABSTRACT
“You Better Eat to Survive” is a two-player virtual reality game that involves eating real food to survive and ultimately escape from a virtual island. We sense eating actions of players by analyzing chewing sounds captured by a low-cost microphone attached to the players’ cheek. Our interest in using cooperative eating as a way of interacting in virtual reality is driven by the possibilities of creating a cross-modal gameplay experience that benefits social interactions. A user study with 22 players showed that eating real food improved players’ feeling of presence, challenged trust dependencies and made the survival aspect of the game feel more *“real”*. We use these insights to articulate three design themes that can guide designers in creating virtual reality games that incorporate cooperative eating. Ultimately, our work aims to guide design thinking towards using underexplored interaction methods in virtual reality games, thereby reiterating the *post-digital design* theme of TEI 2018.

Author Keywords
Virtual reality games; Cooperative Eating; FoodCHI; Human-Food Interaction (HFI); Multisensory Games.

Categories and Subject Descriptors
• Human-centered computing~Virtual reality • Human-centered computing~Collaborative interaction • Human-centered computing~Interaction techniques • Software and its engineering~Interactive games

INTRODUCTION
Virtual Reality (VR) games are increasingly becoming popular [31] and companies like Google, Facebook and Oculus are building platforms and hardware to support the development of VR games. In most VR games, software technology is used to build replicas of the real world through simulations and such experiences are visualized using head-mounted displays (HMDs) [51]. Although VR games can offer an immersive and exciting new way of gaming, interaction options within VR games are still limited [31]. Since commonly used game controllers do not offer an easy and convenient way of interaction in VR, researchers are looking into other ways to interact in a VR environment [13,18,40]. The majority of these works investigate visual and auditory interfaces for interactions in VR [13,40], whereas gustatory and olfactory interfaces have been underexplored, even though studies suggest that supporting the associated senses would benefit VR in facilitating richer gameplay experiences [20,42].

In this work we investigate the use of a gustatory interface, in particular the chewing of food, to control actions in VR games. Eating can offer a rich multisensory social experience [24] that so far has rarely been used in a VR gaming context. Our work also aims to address the feeling of social disconnect in VR environments through cooperative eating, which could add excitement [50] and the feeling of social presence [3] to the VR experience. Drawing on this, we designed and studied *You Better Eat to Survive,* a two-player VR game in which a player has to chew real food (fed by the other player) to survive and ultimately escape from a virtual island (see Figure 1). We detect chewing by analyzing the chewing sounds captured by a low-cost microphone attached to the player’s cheek.

Figure 1. In *You Better Eat to Survive,* the non-VR player feeds the VR player from behind to survive on a virtual island

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We conducted a study with 22 players to understand the user experience of playing *You Better Eat to Survive*. The study findings highlight that eating real food increased players' feeling of presence, challenged trust dependencies and made the survival aspect of the game feel more *"real"*.

Our work makes the following contributions: 1) By presenting *You Better Eat to Survive*, we introduce the opportunity of combining food with virtual reality for an engaging cross-modal gameplay experience that transforms the loss of a sense (i.e. not seeing the food) into an exciting game element. 2) We contribute a first conceptual understanding of the interrelationship between VR and cooperative eating by presenting a descriptive account on the design and user experience of the *You Better Eat to Survive* game. 3) We articulate three design themes to help designers in creating engaging VR games that incorporate eating as a control mechanism.

RELATED WORK

While we use all our bodily senses in everyday life, when it comes to technology design, *"we mostly rely on vision and audition, increasingly harnessing touch, whilst taste and smell remain largely underexploited"* [38]. According to LaValle [31], visual and auditory interfaces become popular in VR because the underlying organs are close to each other in a human body, they are easy to combine with low-cost head tracking and the digitization of audio and sound might be easier as they are measured in frequency [38,48]. Interestingly, Gallace et al. [20] point out advantages of increasing the number of senses stimulated in VR to increase enjoyment, memorability and sense of presence, drawing onto the unique qualities of the gustatory and the olfactory senses, such as inducing positive mood [53] and contributing to long lasting memory [15]. In particular, within the field of *Human-Food Interaction (HFI)* [37] there have been numerous works that explore the relationship between technology and the gustatory as well as the olfactory sense [8,34,38].

Human-Food Interaction

Many works within HFI have focused on altering food perception to improve the consumption experience. For example, Ranasinghe et al. [43] developed the *Spoon+* and *Bottle+* prototypes that can be used to virtually manipulate the taste of food or drinks and may help to replace possibly harmful artificial flavorings. A similar approach to alter the gustation sense was done by Narumi et al. [36] through *MetaCookie+* that uses augmented reality and smells to overlay a cookie with visual and olfactory information thereby changing the perceived taste of the cookie. *Project Nourished* artificially stimulates all senses to offer eating experiences without caloric intake [41].

Playful interactions with food

HFI works also looked into utilizing existing foods to offer playful new experiences [34]. Maynes introduced *Edible User Interfaces* [33] through a system called *TasteScreen*, where users interact with a system by licking liquid residue of different flavors that dripped onto the LCD screen. Khot et al. explored the use of food as a celebratory technology [24] through mixing sports drinks [28] and printing motivational slogans and smileys in chocolate [27] based on an individual's physical activity data. Murer et al. [35] created a haptic input device, *LOLLio* (lollipop) that dynamically changes its flavors thereby offering playful experiences around taste. Not using food but related through its focus on input through the mouth is the work by Tennent et al. [49]. The authors developed a gas mask that utilized the player's breathing as a game mechanic for a computer game where the players had to control their breath at certain points to progress in the game. These works demonstrate that games can benefit from allowing an additional bodily action to be sensed in order to control gameplay and led us to the idea of utilizing eating as a technique to interact with a VR game.

Rationale: Why combine cooperative eating with VR?

Food is not just a source of energy it is also a medium that defines our social and cultural identity [17]. The processes of cooking and eating food together offer opportunities for social bonding [19] and intergenerational play [16] while also supporting a rich multisensory experience. French gastronome Brillat-Savarin [10] notes that pleasures associated with eating and drinking constitute some of the life's most enjoyable experiences. Grevet et al. further highlight the social benefits of commensal mealtimes and their ability to support connectedness [23]. To the best of our understanding, the games research field has yet to explore these benefits particularly in a VR gaming context, which motivated us to do this work. In particular, we were motivated to research the following two opportunities:

1. Utilizing loss of vision in VR as a positive game element

Combining VR running on HMDs and eating leads to the condition that people would not see what they are eating. While this might seem problematic at first glance, our interest is to explore this as an advantage for novel gameplay. Several restaurants are already using VR and the absence of vision of the food to create novel dining experiences [46]. Drawing on this, we explore the design of a VR game that explores eating without seeing what we eat.

2. Bridging VR and the real world through cooperative eating

Wetzel et al. [50] found that adding a social element in a mixed reality environment could enable the sharing of thoughts about the game and thus could prevent players from feeling lonely or disconnected from the real environment. Eating food is an activity that most people enjoy doing with others [39], feeding food to each other is also quite common. However, in most cases, the people who dine together are part of or viewing the same world. We wondered what if the diners view different worlds? For example, one of them is exploring a VR world and the other one is viewing the real world. Drawing on this, we are motivated to create a VR experience that uses the act of feeding to build a bridge between the virtual and the real world [6].

DESIGN PROCESS

You Better Eat to Survive was the result of many explorations, extensive prototyping and iterative game development spanning over half a year. We conducted brainstorming sessions and focus group discussions with members of the research lab to gather diverse insights on how to detect eating behavior, how to relate food to VR and how to inform design decisions on the gameplay.

1) Choosing the VR technology

Our aim was to develop a low-cost VR game to allow a broad audience to experience it. To achieve this, we used mobile virtual reality, i.e. a smartphone paired with a HMD as a gaming device. We further used the Google VR SDK along with Unity 3D to develop our game [22].

2) Detecting eating

In games such as *Minecraft* [52], simulation of eating is used to regain health of the game character. However, our aim was to capture and use a real eating behavior. At first, we considered augmenting kitchen utensils with thermal or sound sensors, similar to the *Context-Aware Kitchen Utilities* [30]. We further developed a prototype of a food detection system that distinguishes between different kinds of food based on electricity flow and then putting these foods on weight measuring scales with an assumption that removing food items from the plate means they are being eaten. However, these approaches did not give consistent results. We therefore looked into capturing a particular eating behavior directly: *chewing*.

Several approaches exist in the literature to sense chewing. For example, Zhang et al. [54] used glasses with integrated skull vibration sensors to sense vibrations caused by chewing. Another approach was developed by Amft et al. [1] who designed earpad sensors measuring air-conducted vibrations to sense chewing. While these approaches can offer more accurate detection of chewing actions, they need costly and sophisticated devices that may not easily integrate well into a mobile gaming scenario. To address this, we came up with the approach of using sound to sense chewing. We attached a microphone to the players' cheek (Figure 2) and measured the variation in sounds during a chewing and non-chewing action to interpret if the person is eating or not.

Figure 2. The game setup for *You Better Eat to Survive*

The microphone captures the audio from the player's cheek to generate a loudness variable. When the loudness variable exceeds a certain threshold it means the player just chewed on something thereby starting the chewing mechanism and the action is counted as one chewing action. When the loudness variable afterwards drops under another threshold and a certain time passed since the chewing began, the chewing process is finished and the program is ready to capture the next chewing action.

3) Relating eating to VR

After deciding on the VR technology and eating actions, we focused our attention on the mapping between the two. After reviewing the literature, we found that there could be three ways in which food and VR can be combined.

Same food in VR and reality

The first approach presents the same food in VR that people consume in reality. The purpose of VR in this case is to augment the food by altering other senses such as the visuals or the smell to have an effect on the perceived taste of the food. One example of this approach is *MetaCookie+*, which alters the smell and appearance of food through augmented reality [36]. Similarly, Ganesh et al. [21] developed a system to augment the plate of children's meals by digitally projecting sad smileys on the plates when healthy food was avoided.

Different food in VR and reality

The second approach is to use different foods (or its representations) in VR and reality. An example of this approach is *Project Nourished*, a multisensory VR system that plays with people's perception by displaying appetizing high calorie food in VR but actually allowing them to consume 3D printed low calorie food [41]. Although the confusion caused by the difference of the food can be an interesting gameplay element, we decided to go with the third approach that shows no food in VR.

No food in VR but food in reality

In this work, we went with not displaying any food in VR but still requiring people to eat food in reality. We find the lack of vision of the food quite intriguing to support new eating experiences as explored in VR restaurants [46]. This approach goes well with the cooperative eating and survival theme of the proposed game, which we describe in the next section.

4) Deciding on the gameplay

The final decision was to identify the right gameplay that connects eating behavior with a VR game. To help us in gaining this understanding, we conducted a two-hour long brainstorming session with 7 participants (3 female, age 23-38) from a research lab with diverse academic backgrounds. In the session we asked the participants to playtest two single player games that demonstrate early concepts of the gameplay. The first game utilized eating as interaction to break down game obstacles in a maze style game. The other game was a 3D platform game in which players could restore health by looking at health icons and simultaneously

eat real food. We further discussed how to enrich the gameplay.

Participants enjoyed playing these games and found eating based interaction novel and exciting. The use of a microphone to detect chewing was not considered uncomfortable or obstructive while playing. However most of the participants felt that the games could utilize more social interactions or some way to connect players with the audience. Some participants stated they felt awkward playing while the others are just watching them not knowing what is happening in the game. This led to the decision to make the game a two-player game that utilizes cooperative eating as an interaction technique within a VR game. Participants also mentioned the contrast between eating and gaming where one can play games for hours but cannot eat for the whole duration. Furthermore, the concept of satiety (i.e. feeling full) after the consumption of food was also debated. The discussion further brought up the topics of using a natural environment as opposed to abstract worlds, and identifying a strong link between the VR world and the eating. These topics guided us in the development of our game. *You Better Eat to Survive* is a multiplayer game that takes advantage of cross-modal gameplay, having two players, one inside VR and the other outside in the real world. Finally, we went with fruit based snacks instead of heavy foods to allow for longer duration of play without feeling full. We explain the gameplay next.

YOU BETTER EAT TO SURVIVE

You Better Eat to Survive is a two player VR game. In this game, one player puts on the VR headset and tries to find a way to call for help after being stranded on a virtual island. This game uses the narrative of a survival adventure game, where the main character has not eaten for days and he/she is on the brink of passing out, thereby constantly losing his/her vision in the game. We refer to the loss of vision as blackout phases and represent them using a steadily shrinking view (Figure 3). The blackout phases are activated throughout the game. The objective of the VR game is to move around the island and find and use different objects via gaze interaction that ultimately lead to a flare gun that is hidden on the island. Once found, the player fires it to call for help and wins the game. Once a blackout phase starts the only way to regain vision in the game is by eating.

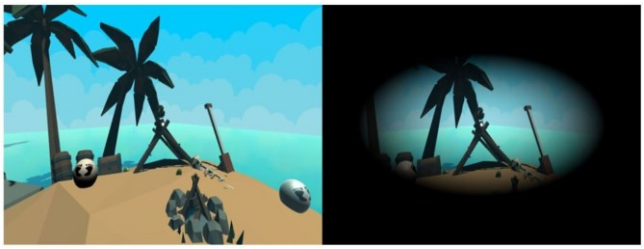

Figure 3. Transition of vision during a blackout phase

We use auditory feedback (digital chewing noises) and visual feedback (virtual crumbs falling down) to visually portray the chewing activity in the game. With every chew, the player's view gets increasingly restored until he/she has full vision again. When the vision is restored fully the microphone is deactivated until the next blackout phase to avoid accidental triggering of the microphone through players' chatting. In case not enough food was eaten or there is no food left, the player dies and loses the game.

A major problem for the VR player is that he/she does not see the food because he/she is wearing the HMD (Figure 1). The food is prepared and rationed on three tables set up in a triangle around the players resembling the playing field. The job of the second player is to lead the VR player around the playing field and both guide him/her to the food and then feed him/her. This creates an intriguing game setup of two players playing the same game but one in the virtual and one in the real world. This setting is enforced by requiring the players to play as one *"shared body across both worlds"* that combines the abilities of the two players: the VR player cannot see the real world or the food but sees the virtual world, while the real world player does not see the virtual world but sees the food and is able to interact with it. In order to win the players need to cooperate: While the VR player tries to discover a way to get help in the game the real world player is in charge of feeding his/her companion to prevent him/her from losing vision in the game. Physically, the players resemble one body because the real world player embraces the VR player from behind and uses his/her own hands as it would be the VR player's hands to feed him/her while the VR player is not allowed to use his/her hands (Figure 1). This confronts the players with the challenge of collaboration and working as a team. To this end, our game aims to facilitate a rich social experience that promotes teamwork. Our game was showcased to a large number of people in the course of the student game competition at CHI 2017 in Denver and won in the category *Innovative Interfaces* [2].

USER STUDY

We conducted a study with 22 participants (9 male, 13 female) to gather insights on the user experience of playing our game. The participants' ages ranged from 18-34 years with an average age of 26 and a standard deviation of 5.

Participants played the game in pairs of two. Each session involved two participants playing the game twice, once as a VR player and once as a feeder. Prior to each session we prepared fresh food and we cleaned and disinfected the HMD and microphone that come in contact with human skin. The participants then received an oral introduction to the game and were asked to choose either the role of the VR player or the role of the feeder and alternating afterwards. The playing session ended when players finished the game or when the food ran out and the participants thereby lost. If the VR player died before the food ran out because the feeder did not manage to feed the food on time, we allowed

them to restart the game and try again. At the end of the study, we asked the participants to fill out the game experience questionnaire (GEQ) [26] and partake in a semi-structured interview that lasted for about 20 minutes.

FINDINGS

We now describe the study findings collected from the three sources of data: 1) video analysis of the gameplay 2) GEQ questionnaire 3) post-study semi-structured interviews.

Video Analysis of Gameplay

To gain insights about player behavior we video recorded all gameplay sessions. This helped us to discover behavioral patterns as described below.

Effective food management

In *You Better Eat to Survive,* the only way to regain vision during blackout phases was to eat real food, which made food an important resource that had to be managed well. Since the food was laid out on a table before the actual game started, both players knew how much food was available to eat. Since the number of blackout phases and their occurrences within the game was unknown, the participants needed to be skilful in determining how much food to eat and how much food to keep for next the blackout phase. Our participants came up with interesting strategies to use the food efficiently: Six players chew food really slowly and stopped when the vision was restored. Four participants continued mimicking the chewing actions even when the food was almost gone in their mouth. Three other participants asked their partners to keep some food pieces ready in their hands as preparation for the next blackout phase.

Winning strategies

We also found that participants were willing to cheat or *"act smartly"* in the game in order to win. In total three different core strategies were observed: one method often used was to illicitly pick food from the same table two or more times before moving to the next table thereby saving precious time to explore the island further. Some VR players cheated and used their own hands to grab and eat the food to save time putting it in their mouth. Lastly, after realizing that chewing is captured via sounds, several participants mimicked the chewing without having any food in their mouth (i.e. by clicking their teeth) in a fashion that would be falsely detected as eating. An interesting fact that came out of the analysis was that the VR players started most forms of cheating. One explanation could be given that the high immersion in the VR game unknowingly prompted the participants to cheat in the game because they forgot that we were observing them.

GEQ Data

We used the GEQ questionnaire [26] to provide us with numerical data about perceived game experiences to supplement the qualitative data from interviews and the video analysis of the observed gameplay. This questionnaire has four different modules: the core module, in-game module, post-game module and social presence. By asking module specific questions, each module provided us with numerical data (on a scale from 1 to 5) about the general game, in-game, post-game and social experiences, which we utilized to understand players' experience of the game [11].

In the core module, the five positive components: *competence, flow, immersion, challenge* and *positive affect* received high ratings (2.67 – 3.95) while the negative components: *tension* and *negative affect* got a 1.50 and 1.23 rating. The post-game module revealed that participants rated the experience as more positive (2.67) than negative (1.97) and inflicted hardly any tiredness (1.27). The results of the social presence module showed high behavioral involvement (3.57) and a psychological involvement with an empathy character (3.20) rather than negative feelings (1.97).

The GEQ results demonstrate that *You Better Eat to Survive* was perceived as a positive game experience that offers behavioral involvement, high immersion and good flow without annoying or tiring the participants. This finding is supported by the qualitative data gathered from the interviews, which we detail next.

Analysis of Interviews

The semi-structured interviews were transcribed using NVIVO [4] with footage coded and transcribed following thematic analysis [9]. Each question asked by the interviewer and the associated answers represented one unit of data generating 199 data units in total. We read and reread all units several times to create a codebook. These codes helped to identify the most interesting features of the data unit to help grouping them together afterwards. In the first iteration of this phase of the thematic analysis we developed 50 codes, for example *"Understanding game mechanics"* or *"Auditory eating feedback"*. In a second iteration we discussed the 50 codes and re-examined them to merge similar codes into broader codes to reduce the complexity. Through this process we decreased the number of codes to 17. Those remaining codes were again re-examined, refined and categorized into groups with the help of two senior researchers. The final outcome of these analytic and evaluative processes is a set of three overarching themes, which we present below.

T1: Using eating to promote feeling of presence in VR

This theme describes how the eating interaction influenced the feeling of presence. There are two aspects to it: Improved feeling of presence through eating and preference of bodily actions.

Improved feeling of presence through eating

The participants felt that eating strengthened their feeling of presence in the game. Participants enjoyed the fact that eating and gameplay are not separated but interlinked as P12 said in the interview, *"using one of your senses, chewing, to do something in a game, definitely feels more*

immersive." P15 similarly said, *"Best bit was how doing things affected the game. Normally when you are playing a game and you sit on the couch and you eat food nothing happens. But when you are playing this game, your eating directly impacts the game it's decidedly odd but in a good way of course."* Participants also appreciated the use of the survival narrative making it a struggle to find the food and eating real food gave them an extra element to connect with the world outside of VR bridging the gap between VR and the external world. As P19 mentioned, *"I was not sort of sealed away in the avatar world, I was still very much part of the real world (through eating)"*. Participants also enjoyed the connection between real world actions of chewing food with a virtual world reaction of regaining vision. For instance, P7 mentioned, *"it was satisfying to hear the crunch sound in your mouth and then your vision repairing in VR as a result of it, it snaps you back to the real world."*

Preference of bodily actions

Although participants liked how eating allowed them to regain energy in a game, they felt that interaction with virtual objects in the game could be further improved. In particular, they found it challenging that they cannot use their body as you would normally use it in the real world. For example P4 disliked the gaze-based interaction with objects: *"Interacting with an object just by looking at it felt a bit weird. I was hoping that I could interact with the objects with my hands. I don't know how that would be done, but may be through external body tracking methods."* P3 also thought that a movement sensor that can track hand movements would be ideal in this scenario. She added, *"It would be cool if there would be a cable going to your hand and capturing your hand movements on screen."* Three participants also suggested integrating walking directly in the game. P14 said *"Yes I would prefer if it was moving in the game so you move sort of yourself. Being able to go everywhere instead of the three different places. And maybe go in the water as well, that would be nice."*

Implications for design

While the two words immersion and presence are often used interchangeably, Slater [47] defines immersion as the objective level of sensory fidelity provided by a VR system and presence refers to the user's subjective response to a VR system. In other words, presence is a personal feeling of *"being there"* that can vary from person to person. Earlier research found that utilizing bodily interactions such as walking within VR helps in creating presence [29,45]. So far, most of the research on bodily interactions in VR is happening around transforming bodily interactions such as gestures [44] or walking [45] in the virtual world to increase presence in VR.

In our study, participants also expressed their wish to use their legs to move around or their arms to interact with objects in the game because using their own body, as they did while eating increased their feeling of presence. Drawing on this, designers could consider implementing traditional bodily interactions, such as hand gestures, to support the feeling of presence. However, as pointed out by Cummings et al. [14], designers would then need to think of the trade-off between the desired level of presence and the associated costs. Besides any monetary expenditure, any high end tracking system would also make the system more complex and cumbersome for users [7,14]. Drawing on these implications, designers can think of using low cost tracking techniques to capture bodily actions such as eating and support the feeling of presence through an engaging game narrative.

T2: Building trust by creating dependencies around cooperative eating activities

This design theme describes the interplay of trust and cooperative eating activities and how it contributed to social engagement among players. The game setup of *You Better Eat to Survive* has one person not seeing what happens in the virtual world and the other person not seeing what happens in the real world. This automatically creates an environment in which players have to depend on each other to stay alive in the game. For the participants, the aspect of feeding was challenging at first, but it also resulted in an enjoyable trust exercise. P21 reflected: *"Having another person feed you with their hands was funny. Something I haven't experienced before."*

Having a partner in the game offered comfort

Participants appreciated the fact that they got to play the game with another person, even though they engaged in different worlds. Having another person allowed the VR players to feel more comfortable and less isolated to explore the island and complete the required goals. P21 added, "*The connection with the real world was really good. It really elevated the game."* Similarly, P15 said, "*I am glad that it is not just like another game where you are isolated in the virtual world."* Participant P22 had a similar experience: *"So when I was going blind in any situation whether you know it is virtual or if it's real it's still scary and there is still a moment of anxiety. So having someone there calms you down immediately and I think that is really helpful and it also drives you to finish the game and you want to do it for the team not just for yourself."*

Eating interaction helped to build trust

The success in the game depended on the proper synchronizations of eating between the two players as P6 said, *"your partner is your eyes to the outside world, helping you survive in the virtual world."* In the beginning, it was frustrating for the players to know that they do not share the same world and do not have the same audio-visual cues. As a result, effective communication became a critical element. For P18, this activity however challenged his trust with the other player: *"It is a real big trust exercise letting somebody guide you and you are basically blind to things you are going to eat. You also have to be really good in communication with somebody else to tell them when to feed and how much."* Participant P22 also agreed that the

survival in the game heavily depended on getting fed at the right moment. She said, *"You must completely put your trust into another person and hope the person behaves in the right way. But it is also a really cool feeling when things work out."*

Coordination of food led to bonding between players

P18 reflected that through the dependencies created by the feeding act, she bonded with her partner while playing: *"So there was a lot of partner work involved which was good because that sort of creates a bonding effect which is really cool. I found it helped me to get to know a stranger much quicker. Even though you are not talking about personal things, you feel like you're bonding because you are helping each other in a situation where you have to communicate and help the other person to survive."*

Implications for design

The study findings reveal that the coordination of feeding and eating activity allowed players to connect even if they were in different worlds (in and outside of VR). Even though eating in the real world might seem to be disadvantageous for the feeling of presence we found that the participants did not feel a break in immersion but rather an increase in immersion through the eating. This might be due to the fast paced nature of the game and the immersive survival theme of the game. We encourage longitudinal in-depth studies on this topic to unfold the correlation between the feeling of presence and eating.

We also found that the food served as a bridge between the two worlds and encouraged a cooperative play experience that values trust. Since 16 of the 22 participants knew each other beforehand, it was easier for them to trust each other on food-related decisions in the game. The situation could be different if the game is played between strangers and could have challenged the trust and dependencies between players. However, as identified in the study, the game narrative and mutual interest of succeeding in the game encouraged players to trust each other right away. Participants also felt rewarded when cooperation led to positive outcomes (i.e., regaining of vision) within the game. Drawing on this, when creating VR experiences that utilize eating as an interaction, designers should consider utilizing the benefits of cross-modal gameplay and having several people playing together even if they are not sharing the same VR game world.

So far, the majority of VR games found in the app stores today are played alone. Research happening around VR and food is also focussed on an individual's food consumption and dining patterns (for examples, see [36,41,46]) while, despite the rich social history of eating, the social aspect of cooperative eating seems underexplored. Eating and feeding interaction as explored in this work could offer possibilities to interact and bond with other people over engaging cross-modal social VR experiences that challenge their trust but also afford moments of comfort through cooperation and coordination.

T3: Encouraging uncomfortable interactions around loss of vision in VR

This theme describes the effects of losing the vision within the game and how cross-modal gameplay helped participants to overcome the challenges of the limited vision.

Losing the vision led to improved focus

In our game, the VR player was constantly on the brink of losing vision in the game. This, at first, caused discomfort among players but also allowed the participants to be more reflective and determined about how they should proceed in the game. P22 mentioned, *"Slowly your vision, from the outside in, starts to be destroyed. Beginning with your peripheral and then moving into your direct line of sight. It was more like an emptiness that came towards me and it snapped me back into the thought of the real world. Since you are losing what you are seeing in front of you, it pushes you to think hard on how you can get back into the game and what you should do to fix this."*

The unpredictability of losing vision caused discomfort but in a good way

Participants found the gameplay challenging and a test of their skills. On the one hand, the act of losing vision caused some anxiety but on the other hand the recovery through eating also resulted in joy and relief. P6 reflected on how the game caused a variety of feelings by saying, *"I had frustration, happiness when the scene lights up again and you get to see the island. You also become excited when you grab objects and complete the required missions. But panic also kicks in when the blackout phase starts. You will then constantly be thinking: 'Am I going to survive? Will the other players be able to feed me at the right time?' So you are excited but you also fear, fear for the things that are not in your control."* P22 described similar changes in emotions during the game. She said, *"So the game starts off and you are all curious to explore the island. But then the anxiety kicks in with the blackout phase and you feel the pumping of your heart."* Most participants however were happy with the discomfort and the sudden rush in adrenalin as P3 described, *"I guess it is a good kind of anxiety and adrenalin. You feel like after you been on a ride or done something a bit crazy that you usually wouldn't do. It's like a healthy amount of fear and that can be a deliberating good feeling."*

Reduced real world cues posed additional challenges

The participants found it difficult to navigate without seeing their surroundings to reach the food but they trusted the non-VR players to guide them in right direction. P13 described her experience: *"I felt strange because I know you had to walk for the food so I was ready to walk but I don't know maybe you should let the other person guide you or you walk on your own. But I think I learned it quite quickly to move with the other person because obviously you don't know which way the food is."* Participant P11 found the time criticality of walking and eating quite exciting. He mentioned: *"I like the time pressure element of*

it: 'Oh okay I need to go but oh crap! I have to eat!' That added an extra level of excitement."

Loss of vision led to perceived feeling of real hunger

During the gameplay, the sight of the food was never visible for the VR players but they knew that during the blackout phase they would be getting some food to eat. Surprisingly, this anticipation for food even led to a perceived feeling of hunger. P10 said, *"I liked the fact that when my eyes getting closed it actually made me feel hungry. It made me hunt for food."*

Implications for design

Using the loss of vision as a game element, as explored in our game, lends itself to earlier works around creating *"uncomfortable interactions"* [5,32]. Traditionally uncomfortable feelings, such as apprehension, are considered *"bad"*. Benford et al. [5] however state that uncomfortable interactions, if carefully applied, can offer benefits for entertainment, enlightenment and social interactions. Following this approach, Brown et al. [12] created *Thaphobos*, a two-player game where one player is *"buried alive"* in a coffin but the coffin acts as the VR gaming environment utilizing discomfort as an enjoyable game element. In another work, Huggard et al. [25] developed a game called *Musical Embrace* where players have to hug a pillow together to control the game, thereby creating uncomfortable interactions that can help to overcome social awkwardness. The study findings support the argument of creating discomfort for positive benefit while interacting in VR environments. Participants did not treat the anxieties of constantly losing the vision within VR and having no vision of the food as negative, rather these aspects were perceived as exciting and crucial parts of the engagement possibly because of the involvement of another player and the consumption of real food. Drawing on this, designers could consider creating an engaging cross-modal narrative that allows players to deal with their anxieties of not having the vision of the food and sensory void by coupling them with another player.

FUTURE WORK

In the next iterations of this work, we aim to work on the following three aspects:

1) Improving detection of chewing.

Although chewing can be captured through sounds as explored in this study, this solution does not work well in loud environments such as public exhibits and game arcades where it would be hard to separate background noise from chewing sound. Moreover, as the chewing is detected through sound, sometimes a simple mimic of a chewing sound rather than the actual chewing is also enough to play the game. To tackle this problem, designers could build systems that utilize noise cancellation to prevent interference through background noise and allow for better detection of chewing. Another option is to use special devices, such as the glasses capturing chewing through muscle movements [54] although this would increase the detection complexity since they require elaborate prototypes.

2) Explore the full design space of eating in VR

As described in our work we implemented cooperative eating to create a novel gaming experience that utilizes the cross-modal gameplay to connect VR players with non-VR player in a playful way, making the focal point of our work cooperative eating in VR games limiting our insights to this subset of eating. To gather more information about the relation between food and VR in a gaming context in general we aim to explore the full design space in the future, including non-cooperative eating experiences and exploring the two approaches that our work did not investigate, namely, showing either the same or different food in VR and in reality. Exploring these two options would help improving our understanding on how eating can influence the other senses while playing a VR game. However, using eating as a game mechanic in VR could lead to players strategically over-eating or remaining hungry in order to win in the game. To avoid this, designers could collaborate with dietitians to sketch out a proper in-game meal plan to restrict over- and under-eating.

CONCLUSION

In this paper, we described the design and study of *You Better Eat to Survive*, a two-player multisensory VR game that offers an underexplored way of interaction - eating - by requiring eating real food to survive and escape from a virtual island. Our aim was to demonstrate that cooperative eating can be an intriguing interaction technique to enrich VR experiences while offering complementary benefits of social interactions around food. Along with the details of the design process, we also described the insights collected from interviews, the questionnaire and the video analysis of gameplay. Through thematic analysis we developed three themes we hope will help designers in creating engaging VR games with cooperative eating as a control mechanism.

To conclude, the technology used to play VR games has been rapidly improved in recent times. The big question is: Can we, as designers, keep up with this swift development and provide VR users with novel interactions that help foster social interactions, provide a high level of presence and utilize the circumstances of HMD gameplay to benefit the experience? As a first step to address this question, we illustrated how eating can be an intriguing interaction technique that enriches VR experiences while offering complementary benefits of social interactions around food. We invite more explorations on cross-modal VR gameplay experiences with eating and provide designers with an initial understanding on how to begin such explorations.

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