Immersive Eating

The virtually enhanced solitary meal context as a strategy to promote positive meal experiences and sufficient energy intake for future generations of older adults

Korsgaard, Dannie Michael

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

IMMERSIVE EATING

THE VIRTUALLY ENHANCED SOLITARY MEAL CONTEXT AS A STRATEGY TO PROMOTE POSITIVE MEAL EXPERIENCES AND SUFFICIENT ENERGY INTAKE FOR FUTURE GENERATIONS OF OLDER ADULTS

BY
DANNIE MICHAEL KORSGAARD

DISSERTATION SUBMITTED 2019

AALBORG UNIVERSITY
DENMARK

Immersive Eating

The virtually enhanced solitary meal context as a strategy to promote positive meal experiences and sufficient energy intake for future generations of older adults

PhD Dissertation

Dannie Michael Korsgaard

Aalborg University Copenhagen
Department of Architecture, Design and Media Technology
A.C. Meyers Vænge 15
DK-2450 Copenhagen SV

Dissertation submitted:	May 2019
PhD supervisor:	Associate Professor Thomas Bjørner Aalborg University
PhD committee:	Associate Professor Cumhur Erkut (chairman) Aalborg University, Copenhagen
	Professor, Vice Dean Karin Wendin Kristianstad University
	Adjunct Professor, Head of Research Agenda and Quality at Ericsson Consumer & Industrylab Michael Björn Lund University School of Economics and Management
PhD Series:	Technical Faculty of IT and Design, Aalborg University
Department:	Department of Architecture, Design and Media Technology

ISSN (online): 2446-1628
ISBN (online): 978-87-7210-441-6

Published by:
Aalborg University Press
Langagervej 2
DK – 9220 Aalborg Ø
Phone: +45 99407140
aauf@forlag.aau.dk
forlag.aau.dk

Printed in Denmark by Rosendahls, 2019

Author CV

Dannie Korsgaard received his Master of Science in Medialogy from Aalborg University in Copenhagen in 2010. Subsequently, he spent two years in industry, working as a software developer. In 2012, he returned to Aalborg University as a research assistant, teaching and assisting with research projects. In 2015, he started his PhD studies as part of the ELDORADO research project, under the supervision of Thomas Bjørner.

Thesis details

Thesis Title:	Immersive Eating: The virtually enhanced solitary meal context as a strategy to promote positive meal experiences and sufficient energy intake for future generations of older adults
Ph.D. Student:	Dannie Michael Korsgaard
Main Supervisor:	Assoc. Prof. Thomas Bjørner, Aalborg University Copenhagen
Cosupervisor:	Assoc. Prof. Armando Perez-Cueto, Copenhagen University
Technical adviser:	Assit. Prof. Paolo Burelli, IT University of Copenhagen
Funding:	The studies conducted as part of this thesis were part of the ELDORADO project "Preventing malnourishment and promoting well-being in the elderly at home through personalised cost-effective food and meal supply". ELDORADO was supported by grant (4105-00009B) from the Innovation Fund Denmark.

The main body of this thesis consist of the following papers.

[A] Korsgaard, Dannie; Bjørner, Thomas; Sørensen, Pernille Krog; Burelli, Paolo; "Creating user models for persona development from qualitative data," *Submitted to the journal of User Modeling and User-Adapted Interaction*, 2019.

[B] Korsgaard, Dannie; Nilsson, Niels Christian; Bjørner, Thomas; "Immersive Eating: Evaluating the Use of Head-Mounted Displays for Mixed reality Meal sessions," *Proceedings of the IEEE 3rd Workshop on Everyday Virtual Reality (WEVR)*, 2017.

[C] Korsgaard, Dannie; Bjørner, Thomas; Nilsson, Niels Christian; "Where would you like to eat? A formative evaluation of mixed-reality solitary meals in virtual environments for older adults with mobility impairments who live alone," *Food Research International*, vol. 117, pp. 30–39, 2018.

[D] Korsgaard, Dannie; Bjørner, Thomas; Sørensen, Pernille Krog; Bruun-Pedersen, Jon Ram; Perez-Cueto, Federico J. A.; "Eating together while being apart: An experimental study on the effects of computer-generated mixed-reality conversations and virtual environments on older eaters' solitary meal experience and food intake," *Submitted to the journal 'Appetite'*, 2019.

[E] Korsgaard, Dannie; Bjørner, Thomas; Bruun-Pedersen, Jon Ram; Sørensen, Pernille Krog; "Older adults eating together in a virtual living room: opportunities and limitations of eating in augmented virtuality," *Proceedings of the 31st European Conference on Cognitive Ergonomics (ECCE)*, 2019.

In addition to the main papers, the following publications have also been made.

[1] Bjørner, Thomas; Korsgaard, Dannie; Reinbach, Helene Christine; Perez-Cueto, Federico J. A.; "A contextual identification of home-living older adults ' positive mealtime practices: A honeycomb model as a framework for joyful aging and the importance of social factors," *Appetite*, vol. 129, pp. 125–134, 2018.

[2] Reinbach, Helene Christine; Bjørner, Thomas; Skov, Thomas; Korsgaard, Dannie Michael; "Use of a combined approach including photo elicitation for characterizing meal intake and food preferences of older adults living at home," *Submitted to the journal 'Appetite'*, 2019.

This thesis has been submitted for assessment in partial fulfillment of the PhD degree. The thesis is based on the submitted or published scientific papers which are listed above. Parts of the papers are used directly or indirectly in the extended summary of the thesis. As part of the assessment, co-author statements have been made available to the assessment committee and are also available at the Faculty. The thesis is not in its present form acceptable for open publication but only in limited and closed circulation as copyright may not be ensured.

Abstract

This thesis is part of work package 3 under the ELDORADO research project. The vision of the ELDORADO project is to investigate and disseminate new initiatives to combat malnutrition among older people living in Denmark. Specifically for work package 3, the purpose was to promote healthy eating habits in future generations of the older adults through the use of information technology (IT). Malnutrition is closely linked to a number of life-degrading consequences, such as functional disability. The search for effective interventions targeted the older group is therefore motivated both by a desire to improve the lives of this population group, but also the concerns of how this population growth will create a greater pressure on the welfare system in the coming years.

Malnutrition is a condition found in every tenth home-living older adult and is characterized by changes to the body and functional disability, caused by a lack of nutrients. In previous studies, a relationship between social isolation and malnutrition in older adults has been observed. In addition specific external factors in the eating context have an influence on how much older people eat. Specifically, studies have shown that the physical environment around the meal both can increase and decrease the amount of food eaten and that humans tend to eat more when eating with well-known meal partners.

This dissertation examines whether virtual social meals in virtual environments likewise can affect the eating experience and the amount of food consumed by the older adults during the solitary meal. This has become interesting due to the distribution a kind of IT in recent years that allows the user to wear a head mounted display on the head, which covers the user's field of vision and hearing with screens and headphones. The contents displayed on the screens and the sound of the headphones are updated according to how the user moves the head and allows the user to experience a virtual reality. A prototype is developed that allows a user to eat a meal while experiencing a mix of the real and virtual world, called mixed reality. In mixed reality, the user experiences that the eating environment is virtual, but that the food, tableware and the user's hands are reproduced similarly to how they are in the real world. It is thus possible for the user to handle the food while the display portrays the illusion of the user sitting in other surroundings and eating. Additionally, the technology allows other eaters, with a similar prototype, to connect to this virtual world wherever they are. Represented by virtual avatars that reproduce movements and dialog, users eating alone in the physical world, can interact

with each other remotely in virtual surroundings. The iterative design process and the results of the evaluations are documented through an expanded summary of an early workshop and the five attached articles that make up the bulk of the dissertation.

The workshop included two focus groups, with older people recruited by convenience sampling in an elderly café, and investigates how the older adults engage in social meals and their attitude to eating with a person they do not know. The older participants also expressed their attitude towards a number of thought-up scenarios where IT facilitates contact between the guests of a social meal. The results show that this group of older adults are more open to eat with others the better they know them and that a large part of the older participants found the presented scenarios with IT both difficult to operate and repulsive.

The first article describe the investigation of techniques for finding patterns in interview data revolving around daily meals and the behavior of older adults. The product of this study is a series of persona descriptions where one of these highlights the solitary meal as undesirable.

The remaining articles document studies that evaluate design iterations of the prototype on a younger group, an older group with walking difficulty and a group of active older adults, respectively. Knowledge is collected through both qualitative and quantitative methods in the form of interviews, hand-eye coordination exercises, video observations, questionnaires and measurement of the older adult's energy intake under a number of controlled conditions. The main results show that the prototype's virtual environment in the last iteration was received positively by the older test participants and made the food appear to be of a better quality compared to eating without the prototype. The prototype with the virtual meal partners made the users laugh and improved their mood after they had virtually eaten together. But neither the virtual environment nor the virtual meal partners increased the energy intake compared to eating without the use of the prototype.

In spite of positive reactions to the prototype in the form of a better eating experience, the group of older adults with walking difficulties responded negatively when asked if they would use a perfected version of the prototype at home. It is expected that the idea of using virtual meal conversations to create an improved context around the solitary meal will become more applicable when newer generations get older, as they are already communicate virtually through different internet platforms.

Resumé

Denne afhandling er en del af arbejdspakke 3 under ELDORADO forskningsprojektet. Visionen med ELDORADO projektet er at undersøge og videreformidle nye muligheder for indsatser mod underernæring blandt hjemmeboende ældre i Danmark. Specifikt for arbejdspakke 3 var formålet at fremme gode madvaner hos kommende generationer af ældre gennem brug af IT. Underernæring er tæt forbundet med en række livs-forringende konsekvenser bl.a. funktionsnedsættelse. Behovet for ny viden omkring indsatser hos den ældre gruppe skyldes derfor både et ønske om at forbedre tilværelsen for denne befolkningsgruppe, men er også økonomisk motiveret da den stigende befolkningsvækst de kommende år vil skabe et større press på velfærdssystemet.

Underernæring er en tilstand som findes hos hver tiende hjemmeboende ældre, hvor kroppen pga. mangel på ernæringstoffer ændres i en sådan grad at det fører til funktionsnedsættelse. Der er i tidligere studier observeret en sammenhæng mellem social isolation og underernæring hos ældre, og at specifikke eksterne faktorer i spise-konteksten har en indflydelse på hvor meget den ældre spiser. Specifikt har studier vist at de fysiske omgivelser omkring måltidet både kan øge og sænke mængden af mad der spises, og at mennesket har en tendens til at spise mere når der spises med velkendte spisepartnere.

Denne afhandling undersøger om virtuelle sociale måltider i virtuelle omgivelser på samme måde kan påvirke spise-oplevelsen og mængden af mad som bliver indtaget af den ældre under alene-måltidet. Dette er interessant fordi der de seneste år er sket en udbredelse af en form for IT, der tillader brugeren at bære et head mounted display på hovedet, som dækker brugerens synsfelt og hørelse med skærme og hovedtelefoner. Indholdet på skærmene og lyden i hovedtelefonerne opdateres efter hvordan brugeren bevæger hovedet og gør at brugeren kan opleve en virtuel virkelighed. En prototype udvikles som muliggører spising af et måltid samtidig med at brugeren oplever et mix af den virkelige og virtuelle verden, kaldet mixed reality. I mixed reality oplever brugeren at spise-omgivelserne er virtuelle, men at maden, service og hænder forsøges gengivet som i den virkelige verden. Det er således muligt for brugeren at håndtere maden, mens udstyret forsøger at skabe en illusionen af at brugeren sidder i andre omgivelser og spiser. Samtidig tillader teknologien også at andre spisende, med en lignende prototype, kan opkoble sig til denne virtuelle verden uanset hvor de befinder sig og gennem en virtuel avatar der gengiver brugerens bevægelser og det der siges kan de spisende interagere mens de spiser

deres alene måltid i virtuelle omgivelser. Den iterative design process og resultaterne af evalueringerne dokumenteres gennem et udvidet referat af en tidlig workshop og de fem vedlagte artikler som udgør hovedparten af afhandlingen.

Workshoppen belyser gennem to fokusgrupper, med ældre udtaget ved bekvemmelighedssampling på en ældre-café, hvordan de ældre inviterer til sociale måltider og deres holdning til at spise med en person de ikke kender, samt hvordan de forholder sig til en række tænkte scenarier, hvor IT faciliterer kontakten mellem gæsterne af et socialt måltid. Resultaterne viser at denne gruppe ældre er mere åbne overfor at spise sammen med andre des bedre de kender dem, og at en stor del af de ældre fandt de præsenterede scenarier med IT både svære at betjene og frastødende.

Den første artikel beskriver et studie som undersøger teknikker til at finde mønstre i interview data omhandlende ældres adfærd i forbindelse med daglige måltider. Produktet fra dette studie er en række persona-beskrivelser, hvor et af disse synliggører at alene-måltidet er uønsket.

De resterende artikler dokumenterer studier som evaluerer design-iterationer af prototypen på henholdsvis en yngre gruppe, en ældre gruppe med gangbesvær og en gruppe aktive ældre. Viden opsamles gennem både kvalitative og kvantitative metoder i form af interviews, koordinations øvelser, video observation, spørgeskemaer og måling af de ældres energi-indtag under en række kontrollerede forhold. De vigtigste resultater viser at prototypens virtuelle omgivelser i den sidste iteration blev modtaget positivt hos de ældre test-personer og fik maden til at fremstå af en bedre kvalitet sammenlignet med spisning uden prototypen. Prototypen med de virtuelle måltidspartnere fik brugerne til at grine og være i bedre humør efter de virtuelt havde spist sammen. Men hverken de virtuelle omgivelser eller virtuelle måltiderspartnere øgede energi-indtaget i sammenligning med at spise uden brug af prototypen.

På trods af positive reaktioner på prototypen i form af en bedre spise-oplevelse, udtalte gruppen med gangbesværede ældre sig negative når de blev spurgt ind til fremtidigt brug af prototypen. Det forventes at idéen med brug af virtuelle måltidssamtaler til at skabe en forbedret kontekst om alene-måltidet vil blive mere anvendelig når nyere generationer bliver ældre, fordi de allerede nu kommunikere virtuelt gennem platforme på internettet.

Contents

List of abbreviations

BMI	body mass index.
DOC	density-based optimal projective clustering.
FAMM	five aspects meal model.
HMD	head mounted display.
IT	information technology.
M3	making the most of mealtimes.
MCA	multiple correspondence analysis.
MNA	mini nutritional assessment.
MR	mixed reality.
SCREEN II	seniors in the community: risk evaluation for eating and nutrition questionnaire.
SNAQ65+	short nutritional assessment questionnaire 65+.
VOIP	voice over internet protocol.
VR	virtual reality.
WP	work package.

Preface

Roadmap

The dissertion is organized into two main parts: an introduction and a collection of papers.

The introduction is divided into five sections following the classic academic structure: background, research aim, methods, summary of contributions, and conclusion. The background introduces the reader to the problem area of undernourishment among older adults and the associated consequences. Details on food intake, a key measurement in the dissertation, are introduced followed by an overview of external influences (also referred to as context) on food intake. The problem area is further delimited to the solitary meal motivated by a subsection of social isolation. Subsequently, IT and immersive displays are introduced with a focus on how these technologies can manipulate the context of a meal.

In the section about the research aim the set of research objectives and questions is described and how these are attempted answered through the studies and workshop contributions. In the method section an overview is provided of the conducted studies, limitations are elaborated together with ethical considerations. Paragraphs with comments on specific parts of the method can also be found here.

Next, the contributions are summarized and the introduction part is finalized by a concluding section containing discussion of the contributions and a set of emerging research questions elicited by the conclusions in this dissertation.

The second part of the thesis are a collection of five papers that make up the bulk of the presented work. Paper A describe the investigation of clustering techniques for finding patterns in interview data about daily meals of older adults and presents a novel approach that solves issues with the existing methods. The reader should be aware that the study described in Paper A may appear disconnected from the remaining papers. As will be outlined in the methods section (Section 3.1), the segmented information produced by the clustering method presented in Paper A served as the basis to find ways to aid a particular target group of older adults. Paper B and Paper C present studies evaluating the feasibility of initial iterations of a developed prototype with a focus on the effect and appropriateness of virtual environments. Paper D and Paper E documents the effects of the final prototype with focus on measures of food intake and the subjective meal experience.

Acknowledgments

Firstly, I would like to thank the organisers of the ELDORADO research project and Innovation Fond Denmark for the opportunity to work with this innovative and novel area. Thanks to all the researcher in ELDORADO for you contributions and input at our regular meeting. Secondly, a special thanks to my main supervisor, Thomas Bjørner, for all the support you have provided me both in terms of advise and assistance, but also for using your network to open doors for me. Thank you for always being patient with me even when I promised more than I could deliver. Also thank you to my co-supervisor Armando Perez-Cueto and technical adviser Paolo Burelli, your input has been invaluable.

I have received much support from people in my working environment. Thanks to colleagues around the office at Aalborg University. In particular I want to thank Niels Nilsson and Jon Ram Bruun-Pedersen, for great and fruitful discussions and supporting work to meet submission deadlines. A special thank you is given to Pernille Krog Sørensen, who along her own studies found time to assist me with the lab work required for three of the five included publications. Signe Okkels, thank you for regular discussions, encouragement, and arrangement of co-writing sessions. Thank you Steven Gelineck for being a fantastic friend and collegaue and making sure that I was able to cross the finish line by taking the time to read and provide feedback on the final sections of this dissertation. A thank you to the Samsung Media Innovation Lab for Education, especially Henrik Schønau Fog and Lars Reng, for supplying equipment used to conduct the main experiment. Thank you, Lene Rasmussen and Lisbeth Schou Andersen for their guidance and help with administrative tasks. The people working at Fælles Service at Aalborg University in Copenhagen also deserve my gratitude, especially Simon Holmen Reventlow Clemmensen who arranged access to a testing location. Thank you to people (Morten Melander Olsen and Kitt Fogh) who due to my bad planning experienced inconveniences, but changed their plans with a smile.

Thank you, for the support I have received from my parents, John and Gunn Korsgaard, as well as my father-in-law, Poul Sørensen, and mother-in-law, Winnie Jensen. This would never have been possible without your help. The biggest thank you goes to my amazing wife, Marianne, and our two lovely daughters, Lara and Lucy, for all your support and the brightens you bring in my life. Lastly, I would also like to dedicate the effort required to finish this work to my son, Lukas. We had too little time together and I miss you dearly...

Part I

Introduction

Chapter 1

Background

Due to a decrease in birth rate and an increase in life expectancy, the older-adult segment now constitutes 13% of the world's population (962 million people), the population of this segment is growing at a rate of around 3% per year [189], and the number of people over age 60 is projected to reach 2.1 billion globally by 2050 [189]. As more older individuals retire, more pressure is put on the younger generations to uphold the welfare system. Currently, of all global regions Europe has the largest portion of older adults, as this group comprises 25% of the region's population, leading to a support ratio of 3.3 workers per retiree[1] [189]. Projections indicate that, by 2050, large parts of the world, including Europe, will have support ratios below 2 workers per retiree [189], with Denmark estimated to have a marginally higher support ratio of just below 2.2 [179]. The growth in this population will be concentrated primarily among the oldest group (above age 80). Within 10 years, the number of Danes aged 80+ is expected to grow by 150,000 persons, corresponding to an increase of 58% [39]. By comparison, the number of Danes aged 65 to 79 grow by only 58,000 persons, or 7% [39]. As age correlates with chronic disability [37], and as the World Health Organization has highlighted functional ability as a crucial ingredient in healthy aging [212], efforts that promote older adults' functional ability are needed to lower older adults' health care expenses [55, 109] and improve their lives.

In old age, the maintenance of functional ability is linked to diet. Insufficient nutrition has been associated with increased risk of functional disability, depression, morbidity, mortality, and decreased quality of life among older adults [4, 95, 105, 186, 195]. Undernutrition is considered synonymous with malnutrition, and the Danish Health Authority defined it as a "lack of energy, protein, and nutrients, which leads to an inexpedient body composition and reduced physical functions"[2] [184]. The self-perpetuating pattern of functional disability and weight loss (which is caused by a lack of energy, protein, and nutrients) makes undernourishment par-

[1] This refers to the number of people in the typical working age range (20 to 64 years), divided by the number of people at or above the typical retirement age of 65.

[2] The Danish Health Authority created this reader-friendly definition by rephrasing the commonly referenced medical definition that the consensus group of the European Society of Clinical Nutrition and Metabolism established [29].

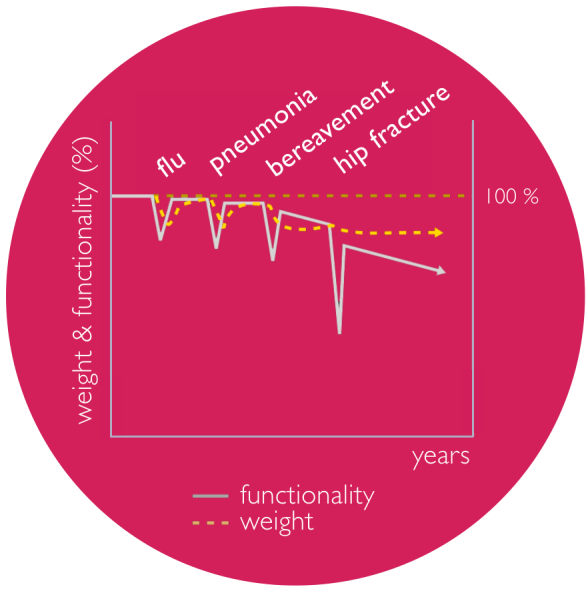

Fig. 1.1: An example illustrating the accumulated decline in weight and functionality due to the negative impact of events such as illness, injury and loss of loved ones. [90].

ticularly dangerous to older adults. Starvation weakens the immune system [131] and triggers the disintegration of the muscle mass that is needed for bodily functions [60]. The mass and strength of muscles in older adults' bodies naturally decline, starting at age 20 [173], but the rate of disintegration (which is known as sarcopenia [37]) increases after age 60 [119]. Loss of muscle strength leads to functional declines such as balance and gait impairments, as well as increased risk of falls [62], and falls are associated with health problems [143]. In cases of injury, illness, or social circumstances, older adults can be caught in patterns of negative cascading events (see Fig. 1.1). Even before forcing older adults into the hospital, illnesses can reduce energy intake [125, 131]; thus, hospitalized older adults are at elevated risk of weight loss and undernourishment during admission [131, 198]. Even with nutritional supplements, these older adults may not regain weight after recovering from the illness or injury that hospitalized them [124], and when they are finally discharged, they are at increased risk of readmission due to their weight loss [61].

Immersive eating was developed as an intervention to counteract undernourishment by intercepting older adults before or after they have started along the trajectory towards undernutrition and its associated negative consequences. The following section is an overview of the prevalence of undernutrition among home-living older Danes.

1.1 Undernourishment among Danish home-living older adults

Many researchers [8, 11, 96] have reported a high prevalence of malnutrition among nursing-home residents and hospitalized older adults, very little data exists about the degree of malnutrition among home-living older adults (and even less exists regarding Denmark specifically). Levels of undernourishment among home-living older adults are difficult to determine, as this group lives in the private sphere and are not necessarily associated with a healthcare organization, unlike older adults who are enrolled in the care system.

According to Danish National Health Survey results, the occurrence of underweight among home-living older adults are rare[3] (0.4% to 0.9% of males and 2.8% to 4.0% of females) compared to significantly overweight (15.0% to 22.0% of males and 13.6% to 17.9% of females) [31, 93]. An explanation could be that the individuals who are the most at risk of undernourishment do not reply to a survey invitation. Low response rates are seen among the oldest participants. For instance, only 50.3% of women over age 75 responded in the 2017 survey [93]. Beck and Ovesen examined for the rate of underweight patients in a sample of 200 Danish older adults who were receiving home care and found that 12% of them were underweight [9]. Other studies from neighboring countries have similar findings regarding the prevalence of malnutrition among home-living older adults. In a Swedish study, researchers recruited home-living older adults from a national register using random selection and found that 14.5 % were at risk of undernourishment[4] [95]. Another Swedish research group recruited participants with the help of nurses who were making preventive-care home visits, finding that 30% of home-living older adults who lacked home-care services were at risk of malnutrition[5] [206]. The researchers in a Dutch study [169] compared two samples of community-dwelling older adults (whom they recruited through general practices and municipalities' population registries, respectively) to one sample of participants who were receiving home care, and the other comprised those who were not. The results of this study indicated that the prevalence of undernourishment[6] was 34.8% in the home-care sample but only 10.7% and 11.8% in the samples of community-dwelling participants [169]. To summarize the literature there is evidence that at least one out of ten home-living older adults in Denmark are malnourished and that undernourishment is even more common among older adults who receive care services.

[3] Being underweight can be an indication of undernourishment but may not be harmful if it does not lead to inexpedient body composition or reduced physical functions.

[4] The authors used the Mini Nutritional Assessment (MNA) screening tool, which consists of measurements and questions designed to rapidly assess the nutritional state of older adults [192]

[5] The authors used the second version of the Seniors in the Community: Risk Evaluation for Eating and Nutrition Questionnaire (SCREEN II). This 17-item questionnaire measures weight changes, dietary habits, appetite, food intake, eating difficulties, use of meal supplements, frequency of solitary or group meals, shopping and cooking [97].

[6] The authors used the Short Nutritional Assessment Questionnaire 65+ (SNAQ65+), which determines undernourishment based on either a mid-upper arm circumference below 25 cm or involuntary weight loss of more than 4 kg in the previous 6 months [207].

1.2 Food intake

The state of undernourishment is defined based on a direct cause: lack of nutrition [29, 184]. Food contains nutrients, which the body (through a chemical process known as metabolism) transforms into the necessary resources. Macronutrients are the compounds that humans consume in the largest quantity: proteins, fats, and carbohydrates. Fats and carbohydrates fuel movement and uphold critical muscular functions (e.g., in the heart and around the lungs) [60, 147]. Older adults are encouraged to eat high-protein foods so as to slow the natural decline in muscle mass that comes with age [58]. Proteins are used to build muscles, as well as to produce important bodily components such as enzymes, hormones, and antibodies [147]. Proteins also act as an energy reserve during starvation [60]. Foods also contain micronutrients, which are needed in smaller amounts and which include the various essential minerals and vitamins. Sufficient levels of vitamin D and calcium are particularly important in old age, as they can prevent bone fractures [58].

Food intake is typically measured in terms of energy intake (the energy extracted from nutrients during metabolism). The terms *meal size* and *food intake* refer to the state of this energy before and during ingestion, but these terms are used interchangeably with *energy intake* in this dissertation. In SI units, energy is measured using joule (J), but in common usage, the calorie (cal) is more common; both measures can use the *kilo* prefix (kJ, kcal). If energy expenditure exceeds energy intake for long periods, the result is weight loss.

The amount of energy contained in a meal is difficult to estimate through inspection without thorough training. Thus, most people rely on appetite and sensations of hunger and satiety to regulate food intake. Herman and Polivy suggest a boundary model for eating regulation [80] (see Fig. 1.2). Fig. 1.2 illustrates the deterministic forces of eating along a continuum divided into three zones. The middle zone represents biological indifference, where eating is determined by non-biological forces. The metabolism will over time pull toward the zone of hunger, while consumption of food pushes toward the satiety zone. When a person is without food long enough and enters the hunger zone, the body signals a deficit in food intake through negative biological reinforcers that urge the person to eat so as to escape hunger and enter biological indifference. If the person eats excessively and enters the aversive zone of satiety, he or she will experience discomfort from a full stomach as a bodily signal of excessive food intake. Physical changes such as those caused by an aging body or medication or disease may alter the distribution of the three zones along the continuum (e.g., earlier satiation) [128, 163, 182].

The zone of biological indifference is not controlled by internal bodily feedback. Instead, a wide set of external factors impact eating. Herman and colleagues argue [81] that a person with unobstructed access to palatable food will attempt to maximize food intake when in the zone of biological indifference until a reason to stop (an external factor) is encountered or ultimately when the zone of satiety is reached. Next, we will provide an overview of the external factors that influence the food intake of older adults.

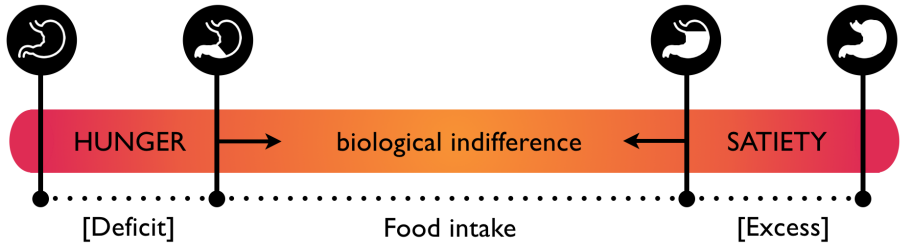

Fig. 1.2: Illustration adapted from the boundary model for regulation of eating originally published by Herman and Polivy [80].

1.3 External factors influencing food intake

The Five Aspects Meal Model (FAMM) published by Edwards and Gustafsson states that the meal experience is the sum of the environment (the room), social interactions with others (the meeting), and the food (the product)[7] [52]. Keller and colleagues expand on this model in the Making the Most of Mealtimes (M3), which was created with a focus on food intake in the context of long-term care in nursing homes [98]. The M3 model links the three aspects of the meal experience with food intake, but due to the authors' nutrition-oriented profession, the model placed strong emphasis on the food aspect. In the following paragraphs, each of the three aspects (food, environment, and others) will be investigated to gain an overview of the external factors that previous work found to affect food intake (see Fig. 1.3).

1.3.1 Food

The older adults will need *access* to the meal before food can be consumed; thus, they must be able and willing to purchase, unpack, cook, and consume the food themselves [139]. Access also entails that foods must comply with potential oral, sensory, and digestive impairments to maximize food intake [98]. Attributes of the food that affect appetite such as sensory appeal (*appearance*, *smell*, *flavor*, and *texture*) also have an effect on food intake [98]. A *varied* selection of foods during a meal will also minimize the chance that sensory-specific satiety (a decrease in the experienced pleasure of tasting a specific food item due to unilateral consumption [164]) will decrease consumption, as alternatives will be readily available [85]. *Portion size* and *nutrient density* are two multipliers that affect food intake. Larger portion sizes have been reported to increase intake in nursing home residents [33, 48], and increased nutrient density increased energy intake in hospitalized older adults [142].

[7] The FAMM model also includes management control as an element of the meal experience, but this aspect is thought to be specific to the restaurant and dietary service domain.

Fig. 1.3: Illustration created by the author displaying external factors influencing food intake of a person eating.

1.3.2 Environment

The physical aspects of the eating environment in which the meal takes place also have an influence on how the older adults experience the meal and how much is eaten [115, 137]. In particular, restaurants are a *type* of environment designed to maximize the guests' meal intake, and meals eaten here are larger compared to meals eaten at home [46]. Aspects of restaurants such as *food salience* [201], the *music or noise* [25, 138, 181, 201], the *lighting* [201], and the *seating and table arrangements* [101] have an influence on how long guests stay and how much they spend (assumed to be indicative of how much they eat/drink). In addition, humans will eat more when staying for prolonged periods in places with a low *temperature*, as more energy is needed to uphold the bodily warmth [201]. The *smell* of a location also has an influence on the human appetite; an unpleasant smell will lower or stop food intake, but smells of palatable food do not necessarily increase consumption, as the smell might provoke sensory-specific satiety [201]. *Disruptions or distractions* in the environment might prolong the meal when viewing television, for instance [83, 201].

1.3.3 Others

Eating a meal in the company of others is a fundamental cultural practice that serves a set of social functions [176], but the mere *presence and number of meal partners* also affects the food intake of the individual eater. It is well documented that social isolation and feelings of loneliness can reduce food intake [22, 193, 200]. In contrast, studies examining the social

facilitation of eating show that meals eaten with *familiar others* (friends or family) increase food consumption [78], but eating with strangers tends to lower food intake [32]. Some studies also suggest that the social effect on intake caused by eating with friends is greater in the *male gender* [14, 100]. *The appearance* of the eater and the meal partners has also been linked to food intake. Meal partners with impairments that cause them to drool or otherwise appear unappetizing may cause a reduction in food intake. From the eater's perspective, believing that one's appearance will repel others can lead to feelings of fear and shame as well as reduced intake in the presence of others [54, 92]. Other studies have shown that the overweight eater will increase food intake when eating with meal partners who appear overweight compared to eating with non-overweight meal partners [82, 167]. Finally, people tend to mimic others' eating behavior when eating together, and thus the *meal size of meal partners* will influence the food consumed by the individual eater of a social meal [36, 81].

1.4 The solitary meal and social isolation

Older adults tend to eat more solitary meals compared to other demographic groups [46]. The prevalence of solitary meals among older adults may be attributed to factors that limit them from engaging in social meals, such as family bereavement [194], sickness, impairments, and age-related decrease in physical activity [49, 122] in combination with circumstances such as living in remote areas or limited transportation options. Despite the commonness of solitary meals in the older age group, eating alone remains sparsely studied and is often only mentioned as the counterpart to social meals.

It has been found that older people eating alone eat less than when they eat with peers [117]. When meal partners are absent, social norms of when and what to eat are not adhered to [193], and the older adults may to a larger degree rely on sensations of hunger and satiety to regulate food consumption [108]. As people age, these fine-tuned sensations may become impaired and lead to insufficient energy intake [105, 127, 182]. While some older adults prefer to eat alone [51], the experience of eating a solitary meal is often described as less enjoyable when compared with meals eaten in company [27, 174, 208].

The food ingested when eating alone consists of more cold meals and snacks compared to social meals [139, 202]. The environment also influences the experience of solitary meals. For instance, negative feelings induced by eating alone may evolve into feelings of discomfort when eating alone in public spaces [174]. Older adults with impairments that restrict mobility will eat most meals in their homes. The home-like environment has generally been thought to be a positive eating environment. The most memorable meal experiences among younger demographics have been linked to feelings of "being at home" [106], and nursing homes strive to decorate common eating areas to resemble residents' homes [87]. However, examples have been seen of older adults mitigating the negative feelings of eating alone in their homes by eating the meals faster [129], using entertainment as a distraction, or by turning on the radio or TV to create a quasi-social environment [129, 174]. The perception of a home eating environment is different from individual to individual, and food may be consumed in various locations in

the home (e.g., kitchen, bed, living room) [108]. Therefore, it is not surprising that studies report both positive [106] and negative [149] experiences associated with eating at home, as the meanings and emotions that one attaches to a place are highly individual. Another factor that may contribute to negative emotions of the home is the amount of time spent there. Eating every meal in the same surroundings may become monotonous over time and therefore reduce the pleasure component of eating a meal in the home, similar to the more extreme cases of sensory deprivation and solitary confinement [34, 183].

If an individual seldom communicates with others, he or she is socially isolated. Social isolation is often described as a risk indicator for malnutrition among older adults [193]. Vesnaver and Keller [193] and Pierce [148] elaborate on some of the mechanisms by which social relationships influence diet in the older age group. Their works build heavily on the theoretical model by Rook [165]. They outline three social mechanisms, namely social integration, companionship, and social support (see Table 1.1). Social integration is when being around others motivates the older individual to adhere to dietary norms (e.g., three meals a day of a certain size). The integration can be both indirect and direct. The indirect integration constrains behavior based on the individuals sense of obligation to others, and the meaning and purpose of the relationships shared with them. An example is the older woman who maintain self-care to be able uphold her role as mother and grandmother for her children and their children. The direct version is when a person directly enforces the norms (e.g., a daughter who visits her old father regularly to cook him dinner and eat it with him to ensure he eats enough).

Social Integration	Social contact encourages compliance with societal dietary norms and norms within the individual relationship. Social integration can be indirect (social contact reinforces felt obligations and norms) or direct (intended control of eating behavior).
Companionship	Companionship includes enjoyable interactions and shared activities with others that result in feelings of well-being and intimacy.
Social Support	Social support includes social resources that are available or are perceived to be available in response to a stress. Social resources can be either tangible, emotional, or informational assistance.

Table 1.1: Overview of the social mechanisms that influence food intake among older adults, adapted from Vesnaver and Keller [193].

Companionship refers to the enjoyable social interactions the older adults have during meals with others. These interactions may have an indirect influence on food intake through improved mood and increased self-esteem [193], but the evidence involving older adults is rather sparse, and none of the studies presented in Pierce's review found significant results [148]. Social support includes the resources that are available or are perceived to be available to the older adult in response to a stress. The goal of whoever provides the support is to help the older person through a period of stress [148]. Because food consumption is an everyday event, many types of stress have the potential to affect nutritional intake, from daily hassles such as running

out of milk to life events such as bereavement or a chronic stress such as a disability [148]. The support offered may come as tangible (e.g. shopping or cooking), emotional (empathy), or informational assistance (advice, googling, etc.) [193].

1.5 Information technology and immersive displays allow manipulation of external factors

IT or information technology is the use of computers to send, receive, store, and manipulate information [1]. The smartphone is an example of how IT has become an increasingly larger part of how people experience the world (e.g., navigation through environments with aid from GPS, communication with others over social media, etc.). A range of literature has demonstrated how IT in combination with immersive displays has altered the perception of the three external factors of the meal experience: the environment, the food, and social interactions (outlined in Section 1.3).

1.5.1 Immersion, presence, and virtual eating environments

The input from people's senses makes up the reality they experience. By covering the senses with virtual input, IT allows people to experience a virtual reality (VR). The degree to which a system covers the senses is often referred to as *immersion*. An example of displays that provide a high level of immersion is the head-mounted display (HMD). An HMD is, as the name prescribes, worn on the head and is able to display stereoscopic images tailored for the left and right eye, and it covers a large portion of the field of view. The built-in head-tracking capabilities of the HMD enable the images to be updated for each eye creating the illusion of looking around in the VR. Utilizing the power of modern graphics cards and 3D rendering engines makes it possible to create virtual eating environments in software and to render images for both eyes in real-time and display them in an HMD. The result is the possibility to explore the virtual eating environment, while experiencing a sense of being in it, often refereed to as the sensation of *presence* [38, 172, 175].

If the user experiences presence in a virtual eating environment, the users may react similarly to how they would in a real eating environment [91]. Few studies [2, 7, 67] have been published, suggesting that virtual eating environments may elicit the same effects as real eating environments. A study had participants experience a virtual beach, and it found that they had a stronger desire for cold beverages over hot beverages, but this was not the case in the neutral lab setting [2]. Another example is a study that used large screens to give people in tasting booths the experience of sitting in a coffeehouse, and it found that hedonic evaluations of the coffee given in the virtual coffeehouse were a more reliable predictor of future coffee preferences compared to traditional tasting booths [7]. The limited research in this area motivates the design of a solitary meal experience in a virtual environment optimized for increased food intake to examine whether the virtual cues may result in real effects due to the presence-inducing capabilities

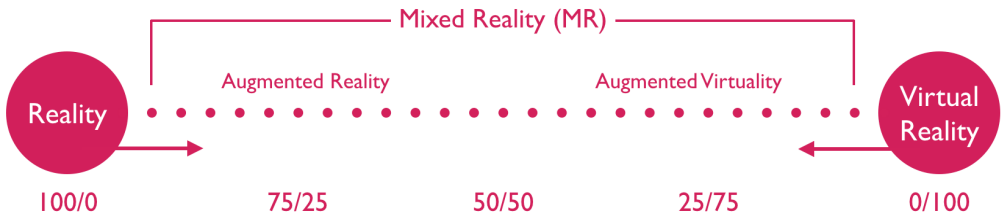

Fig. 1.4: The reality-virtuality continuum [123].

of immersive systems. However, this requires the user of the system to handle and interact with real food while experiencing the virtual environment.

1.5.2 Interaction with food through the use of mixed reality

Certain HMDs use optical or video-based techniques to display a mix between virtual and real elements [104]. This blend is expressed by the reality-virtuality continuum (see Fig. 1.4) published by Milgram and colleagues [123]. The axis spanning between reality and VR represents a ratio between the quantity of real and virtual elements being displayed and this space is often referred to as mixed reality (MR). Most of the affordable commercial consumer HMDs are limited to only show VR (most notable the Oculus Rift [141] and the HTC Vive [88]). Recently, commercial products have been announced capable of displaying augmented reality where the user is presented reality with a few virtual elements (Magic Leap [112] and Microsoft HoloLens [121]). Very few products have been announced or released able to display augmented virtuality that includes specific elements (e.g. hands and food) from the real world into the virtual reality (the most well-known is the discontinued Project Alloy from Intel [162]).

While MR systems allow for interaction with food, they also allow for manipulation of food cues. An example of how food perception can be manipulated using MR is seen in the study by Narumi and colleagues [133] who used a custom built MR HMD to manipulate satiety perception. By the use of image processing techniques the HMD increased the size of the food items being eaten, which led to an earlier onset of satiety. Besides appearance [133, 134], the smell [23, 134], flavour [132, 134, 155] and texture [102] of the food can be altered as well. Using a similar HMD with an olfactory display attached, Narumi and his collegaues demonstrated in another study [134] that virtually induced smell and visuals were able to change the flavor perception of a plain cookie. Manipulation of flavor perception has also been demonstrated using computer controlled delivery of tasteful liquids [132] and electric stimulation [155]. Manipulation of food texture has been done by Koizumi and colleagues [102] who used a photoreceptor and a bone-conduction speaker to add to the sounds and vibrations caused by chewing the food, resulting in altered texture perceptions. Virtual representations of food have also been demonstrated to have an effect on the meal experience. A study found virtual food, in virtual environments viewed through an HMD, to result in emotional responses equal to that of real

food exposure [67]. However, it has also been found that cravings were lower when virtual food environments were seen on pictures and through an HMD compared to looking at real food [107]. The authors of the latter study argue that the difference between real and virtual food could be reduced by improving the visual quality and by adding sensory inputs such as olfactory features [107].

A virtual experience able to incorporate representations of food using MR may make it possible to eat solitary meals in virtual surroundings with the potential to manipulate external factors such as the food (see Section 1.3.1) and the environment (see Section 1.3.1) to support increased food intake of older users.

1.5.3 Copresence and the perception of virtual others

Technology has previously been used to create the perception of social interactions between remote eaters [70, 77, 135, 204, 205]. Solutions applying voice over internet protocol (VOIP) have been found to improve meal satisfaction, mood, appetite, and motivation to eat [86] while lowering feelings of isolation and loneliness [188].

With the recent commercialization of VR products a set of software products have been released under the category know as social VR (such as Facebook spaces [57], AltSpaceVR [120], and Bigscreen [16]). Social VR connects users similar to VOIP solutions but takes advantage of the immersion offered by the technology to create the illusion of being placed in a shared environment rather than observing each other in seperate environments - such as looking through a window. A social VR application will allow the user to interact with other users through puppeteering of virtual avatars. As a minimum the head-tracking in the HMD will transfer head movements to the avatars head and kinematics will ensure that the rest of the avatars body moves accordingly. The voice of the users are captured by a built-in microphone in the user's HMD and are broadcast to the other virtual users to allow conversation. This enables both verbal and non-verbal social interactions (non-verbal through head movements) to take place virtually between the users even though they might be physically located in different parts of the world [136]. The heightened immersion and presence created by such a system can lead the user to uphold a private distance to surrounding avatars [6, 209] similar to the private space people maintain to each other in real life [74]. This observation suggests that users of immersive systems experience a sense of *copresence*. Copresence was originally defined by Erving Goffman as "the reciprocal influence of individuals when in one another's immediate physical presence" [64].

Thus, if copresence exists in immersive systems the effects on food intake caused by the influence of others might also apply in social VR applications. But unlike reality, immersive systems can be designed for increased food intake. For instance, since the avatars are 3D models their appearance can be altered to fit the optimal eating situation and hide features of the eaters real appearance that may hinder optimal food intake (see Section 1.3.3).

1.6 Immersive eating as a facilitator for increased food intake

MR systems allow a high degree of control over the three external factors affecting food intake (the environment, the food, and the social interactions with others). Older adults eating most meals alone are prone to the risk factors leading to undernourishment. Thus, this group might benefit from eating solitary meals while using a MR system to enhance the eating context with the aim of increasing food intake. The scope of this dissertation allowed investigation of two types of facilitation of eating, namely social facilitation of eating and what we refer to as environmental facilitation of eating. Each of the facilitators will be treated in more detailed in the following sections.

1.6.1 Social facilitation of eating

As outlined in Section 1.3.3 eating with others can cause an increase in food intake. Social facilitation of eating refers to an increase in food intake observed when eating in a restricted group of co-eaters compared to eating alone [78]. The most prominent researcher in documenting the characteristics of this effect is de Castro. He conducted a series of food diary studies [28, 42–45, 47] in which he accumulated an extensive data set that documents the effects of social facilitation of eating. An early study revealed that people eating in groups ate 44% more on average compared to people eating alone [28] and that a social correlation exists between food intake and group size such that the food intake of each group member increases as a function of the group size (individuals eating together in larger groups eat more than individuals eating together in smaller groups). In the years following his discovery of social facilitation of eating he did more studies with colleagues uncovering potential covariations and found the social correlation to be independent of other variables such as the time of week (weekday or weekend) [43], time of day (breakfast, lunch, dinner) [47], environment (home or restaurant) [47], type-of-meal (meal or snacks) [47], and meals consumed with and without alcohol [47]. de Castro and Brewer also found the social correlation not to be linear, but instead to resemble a power function in which each new member to the group of eaters increased consumption by a smaller and smaller amount [42]. A set of experimental studies [15, 32, 84, 100, 145, 158] have documented the effects of social facilitation of eating, but the social correlation has not been consistently found [32]. Social facilitation of eating has been observed among all age groups (including older adults) [110, 117, 145]. The effect is often more prominent between friends and family than among strangers [32] and among male eaters compared to female eaters [14, 100] (see also Section 1.3.3). A set of social mechanisms have been found to moderate the effect of social facilitation. They can be summarized into two categories, namely impression management and modelling.

Impression management and modelling

Impression management refers to the situation where the eater believes he or she is being observed or evaluated (see [190] for a set of stereotypes associated with food intake) and as a result

the eater eats less compared to when they eat alone. As an example an individual may eat less or refrain from eating high-fat desserts [32] to express femininity, politeness or self-control to another person. In general people do not want to be perceived as eating excessively (more than the meal partners) [81]. There exists documentation of self-presentation being more modest among friends compared to strangers [24] and this might be why impression management is the social pattern that explains why we tend to eat less when eating with strangers compared to friends and family.

Modelling refers to the situation where a person is influenced by cues from others that signal the appropriate amount of food to eat during a meal [36, 81]. When meal partners mutually influence each other a social norm is established of the amount of food they consume to match that of their companion(s). This effect is very robust and has been observed in people who have not eaten for 24 hours, among children, and even if only a written message with an indication of the amount of food consumed by a prior attendee is received by a participant [191].

The social context of a meal will either increase (familiarity, more meal partners, male eaters) or decrease (impression management) the food consumed during the meal. A list is presented in the next section of the causality propositions leading to increased food intake. This list summarizes the theories presented in the literature on the social influences on food intake.

Causality propositions

A set of ideas have been proposed as to why food intake increases when people eat together. Combinations of the propositions below may likely be the reasons for increased food intake during social meals.

Increased tastiness: Our perception of food might be altered by the presence of others. A study by Boothby et al. [21] concluded that eating experiences (both pleasant and unpleasant) are amplified when shared with another person. As people usually eat more of the food that they have a preference for [3], social facilitation may be the result of eating extensively because the food is perceived as more tasty when in the company of others. However, in a study by Bellisle and Dalix [13] food was rated more palatable in the social condition, but it did not result in increased food intake. The authors state that the social groups consisted of strangers and that this could be the reason why the social facilitation of eating effect was absent.

Distraction: Another idea highlights that social interaction with eating partners may cause the eater to loss awareness of the amount of food being consumed. The distraction caused by the presence of others have therefore been proposed as the reason for increased consumption [84]. However, while the distraction of co-eaters might have an effect on food intake it does not explain the full complexity of social influence on food intake. As an example eating with a stranger would cause distraction, but food intake has seldom been reported to increase when strangers eat together [32, 44].

Excessive supply of food: Herman makes the point that when one invites friends for dinner it is common courtesy to prepare or order more food than would normally suffice [78]. Thus, the reason of why more food is eaten in groups may simply be the availability of more palatable food.

Modelling: Modelling combined with overestimation has been proposed as a cause of social facilitation of eating. 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 [79]. Increased intake by modelling may also occur through social integration when an older adult who normally eats insufficiently starts to attend meals with co-eaters who eats sufficiently [193].

Reduced guilt or judgement: An alternative suggestion states that social facilitation leads to increased portion sizes, as people use good company as an excuse to overindulge [79]. The idea is that sharing the guilt of overeating with others reduces the guilt felt by the individual eaters. This may also be why it has been speculated that cakes (and other high-fat desserts) are more likely eaten in social settings [84, 146]. Similarly, eating excessively increases the risk of being evaluated negatively by others, but eating with others who are perceived as being less likely to judge, such as friends or family [44] or others who eat excessively [116], might cause the individual to become less self-conscious and increase food intake [78].

No reasons to stop (time extension): de Castro [41] proposed that enjoyable company leads to an extension of the eating session rather than an increase in eating pace. Being exposed to food cues for longer are thus expected to increase intake [41, 150]. Similarly, Herman et al. [81] defined an inhibitory model outlining that access to palatable food encourages normative eaters to eat, until a compelling reason to stop is encountered (e.g., pending activities, lack of food, guilt, or satiety). The effect of social facilitation might therefore be caused by the absence of reasons to stop eating.

Arousal and emotion: Based on a review of the first literature of social facilitation effects (in both animals and humans), Zanjonc [213] proposed his generalized drive theory, stating that a person in the presence of others will experience an arousal (drive) response (maybe as a result of having to enact ones societal role [63]). The onset of arousal will enhance the likelihood that the person will resort to the dominant response to a stimuli [213]. Herman and colleagues [81] proposed that the dominant response, when being exposed to palatable food is to eat when no inhibitory forces (such as satiety) are present. As Zanjonc explicitly highlighted a study [156], in which grouped rats attempted to drink water twice as often as solitary rats, as evidence of his theory, the presumed effect of heightened arousal would be an increase in consumption rate. de Castro disagreed with this notion and points to a calming-effect (disinhibition) [154] of having friends of family nearby as an explanation of why we eat more with familiar others compared to strangers [44]. A calming-effect might also be what enables older people with many social resources to acquire more of the necessary nutrients through their diet during a stress (as they know that help is not far away and in high supply) [148]. The area of emotion and consumption is in general rather multifaceted and complex [111] with both negative and positive emotions having been linked to increased food intake [146]. However, Evers and colleagues [56] emphasize the importance of pleasant emotions as a neglected and under-researched trigger for indulgence in palatable foods. When people share meals with friends they often enjoy themselves (companionship [193]) which may lead to increased consumption. Evers and colleagues presents some theories as to why this is, such as

pleasant feelings being associated with eating more food, or that pleasant emotions signal safety and thus evolution has biased a person to eat food to build resources, or that hedonic food are more pleasurable when consumed when positive emotions are experienced [56].

1.6.2 Environmental facilitation of eating

Some evidence suggests that the food intake of individuals is influenced by the environment (see Section 1.3.2). To use similar terms, these type of influences are referred to as "environmental facilitation of eating". When technology is able to create a sense of presence in the user, virtual environments may similarly be able to provide environmental facilitation of eating. More details on this concept will be provided in the following paragraphs.

Meanings associated with a place

A segment of space is in literature referred to as a place [168]. A place is given an identity based on the activities and meanings associated with it [159]. Gustafson developed a three-pole model to classify the meanings attributed a place [72]. The three poles are *self* (personal meanings), *others* (perception of inhabitants) and *environment* (location, type and distinctive features). According to the model, *self* can often be linked to environments, for instance when an environment appear to facilitate the same kind of activities as ones workplace, elicit personal emotions such as a sense of security, or represent who you are. *Others* refer to the identity of a place based on the impressions of the people occupying the place. As an example a place might be meaningful exclusively because it is the house of ones family or because immigrants tend to live there. The *environment* experienced in a place contributes to the identity through attributes of the physical setting (such as the weather), symbolic or historical meaning. An environment may also be thought of as being of a particular type (e.g. city or country side). The meanings of a place can be a weighted mix of two or all three of the poles [72]. These meanings can in turn shape the atmosphere of the place.

Foods may also be associated with a particular place or occasion and since these meanings are learned the associations differ across culture [114]. These associations are formed through repeated exposures and sculpt food acceptance and preference in particular physical settings [2, 53, 118]. It has been proposed that the learned link between food and the situation (place or occasion) will elicit increased/decreased liking of a food if the situation is congruent/incongruent to the expectations [2]. As people usually eat more of the food that they have a preference for [3], having congruency between foods and the eating environments is expected to increase food intake. The foods may also be tied together with the three-pole model. For instance the smell of a particular food may elicit memories of ones childhood home (self), or a particular street-shop might be where one can get those delicious donuts (environment). One can also imagine a scenario where a particular set of friends (others) meet up in a particular restaurant to eat excessively of a particular dish [78].

Atmosphere

Gustafson [72] places the affective capabilities of a place both as an attribute of self (emotion) and as an attribute between the environment and others (atmosphere). Böhme [19] has from an architectural point of view found atmosphere to be the relation between environmental qualities and human affective states. Böhme [20] outlines three groups of characteristics of the environment used to create spaces with certain atmospheres: *Intimations of movement* in geometric structures and constellations of architecture (e.g. massiveness or loads, confines or expanse), *synesthetic properties* are those that are picked up by more than one sense at the same time (e.g. a sharp tone, cold blue), *social characteristics* are culture specific (e.g. the atmosphere of the fifties) and relates to the meanings of a place described previously.

The concept of atmosphere has been further elaborated in an eating context by the Five Aspects Meal Model (FAMM) [73]. From the perspective of servicescapes the FAMM defines atmosphere as the perception of "the entirety of the meal" and state that it is the sum of the room (eating environment), the meeting (social interaction during the meal) and the product (the food/beverage/service). Interesting to our study FAMM expands on the definition of atmosphere by Böhme [19] stating that characteristics of the food (e.g. collation, color, smell, taste) have an effect on the affective capabilities of a place. In a study students reported the atmosphere of their most memorable meals to elicit feelings of "being at home" or sensations of relaxation and comfort [106].

Engagement

Eating in a distracting environment is in its essence multi-tasking. As humans we only have a certain amount of mental resources which can be directed towards a stimuli. When the eater engages in observation of the environment the awareness of the food eaten decreases. One can think of extreme cases where this might happen such as restaurants where guests eats while viewing a live performance and similar to TV-viewing, but this might also happen to a milder degree during solitary meals in interesting or distracting environments. O'Brian and Toms describe engagement as a process with a start, middle, and an end with possibility of re-engagement [140]. Initial impressions of the environments novelty and aesthetics of the environment will convince the user to invest mental resources into exploring the environment (from the stationary point where the user is sitting) [140]. Re-engagement is when a user returns to being engaged after disengagement. Specific types of engagement have also been suggested, which seem directly related to eating environments. Schønau-Fog and Bjørner mention *sensory engagement* as one of six types of engagement which leads to a desire for re-engagement [170]. They define sensory engagement as the desire to continue exploring the sensory elements of an environment. Notably, they refer to the work of Calleja, who describes how players' of massive multiplayer online games engage in the process of familiarizing themselves with a large-scale virtual environment [26]. The process of exploration and learning the layout, landmarks, and sounds of the virtual environment results in mental images of the space (place identity) and a sense of habitation, comfort and feelings of belonging [26]. When a player has become famil-

iar with an environment mental resources will be freed and directed towards activities in the environment [26]. Exploration is a natural part of encountering new environments, but Ryan describes how exploration of an environment can be used in a narrative fashion to invoke motivation and pleasure: "When participation takes the form of spatial exploration and leads to unexpected discoveries, its motivation is curiosity, and its reward is surprise" [166]. Summarizing, the point of sensory engagement occurs when a novel or visually interesting environment is presented to a person. The person will naturally start an exploration process to become familiar with the space and begin the construction of a place identity based on sensory impressions and ongoing activities, as well as personal, social and symbolic meanings associated with the place. The disengagement might happen, when the place identity becomes exhausted and the person has explored everything, if the place identity is uncomfortable, or due to any of the causes listed by O'Brian and Toms, such as usability problems, frustrations, and interruptions [140].

Causality propositions

Many of the causality propositions for increased food intake from social facilitation may also apply to environmental facilitation. Theories outlined in literature of why particular attributes of the environment may increased food intake are listed below.

Bodily response: Particular sensory impressions in the environment can influence appetite (e.g., disgust), but also choice of food or drinks [2].

Learned behavior: The reason why restaurants tend to motivate high consumption of foods [46], could be explained by previous experiences, which create expectations of palatable food and motivation for emptying each plate as the guest still has to pay for the food not consumed.

Distraction: An engaging environment may cause the eater to loss awareness of the amount of food being consumed, similar to how food intake can increase when watching TV [84].

No reasons to stop (time extension): This builds on Herman and colleagues' inhibitory model, which states that an eater will continue to eat until a compelling reason to stop is encountered [81]. If an environment offers no reasons to stop it will promote more food intake compared to an environment with comprehensive reasons to stop.

Arousal and emotion: The atmosphere of an environment may also have direct influence on the mood of the eater [178, 180] resulting in any of the complex interactions between food intake and emotions [111]. Depending on whether the atmosphere elicits positive or negative emotions the eater will either be motivated to stay and continue to eat in the environment or be motivated to leave.

1.6.3 Putting it all together

To aid in the understanding of how the presented concepts relate, a model is here used to display associations between the concepts and can be seen in Fig. 1.5. The model uses the same trisection as Fig. 1.3 to display external factors of meal context that has been found to influence food intake, but food is only represented with a title and an icon since the concepts introduced revolve more around the environment and social interaction with others. The concepts treated in

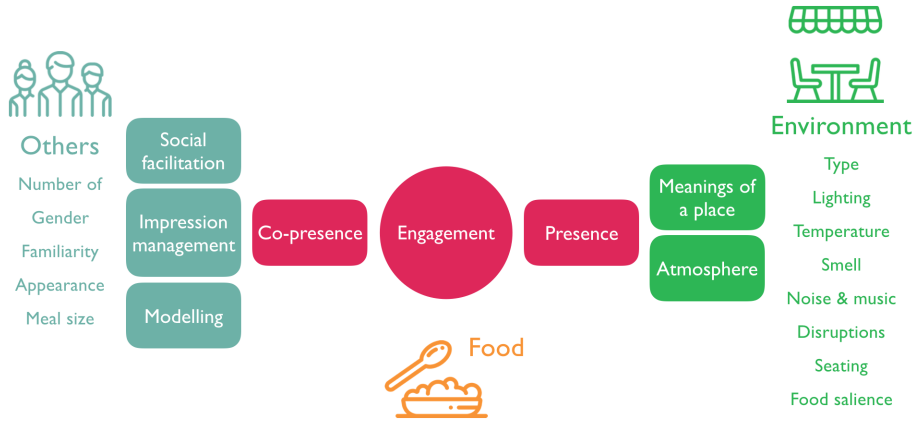

Fig. 1.5: A model used to reflect on the associations between the presented concepts.

the previous subsections are displayed as rounded rectangles, with exception of "engagement", and distances between them and color selection are meant to represent respectively level of association and affiliation.

Engagement is visualized as a circle in the center of the model to represent how an eaters attention can be shifted around between the three elements of the food context: food, environment and others. Depending on the appeal of the element that receives attention the eater may enter the state of engagement. Engagement is in the text placed in relation to the environment, but is also relevant in terms of food, others and the environment. This is also visible when considering distraction as a common causality propositions for both social and environmental facilitation (e.g., both the social interactions and the environment may engage the eater to a point where self-monitoring of food intake is neglected).

To use immersive technology to manipulate the perceptions of the physical environment it is thought to be a prerequisite that the artificial input (e.g., the light emitted from pixels in the screens on an HMD) can be perceived as an environment, but also that the input elicits a high sensation of presence. An example to illustrate the difference between eating with high and low presence could be to eat a meal while being in the environment (high presence) compared to looking at a picture of the environment (low presence). With an image the eater has a low sense of being in the environment as there are no interactivity (not able to orient ones head to look around) and sensory information is missing in all channels (e.g., not able to hear sounds of the environment, a small visual size - not extending to the edge of the field of view) [**?**]. It is likely that the eater in both the high and low presence scenarios will be able to derive meanings of the environment and experience the atmosphere that the environment elicits, but the perceptions will be incomplete in the low presences scenario. A picture will not carry the full information as sound is missing and the picture might not be in full 360 degrees panoramic. The image might still be able to promote bodily responses such as disgust or increased desire for

food (e.g., known from food advertisement), but the intensity of the experience is thought to be more penetrating when a high level of presence is experienced. Presence might also be similar important to utilize social facilitation through technology. Schroeder argued that co-presence tends to increase with presence but that factors influencing co-presence are more complex [171]. For instance, the realism of the avatars might result in a low sense of co-presence even though the HMD induces a high sense of presence [171]. However, for now it is placed in the direction towards the environmental factors to highlight its importance in environmental facilitation. The foundation for utilizing immersive technology to increase food intake through social facilitation is a sensation of co-presence felt by the eater. The realism and responsiveness of the avatars used to create the illusion of social meal partners influences the intensity of co-presence [171]. A high co-presence will result in solitary eaters that display behavior similar to that seen in social meals, such as social facilitation, impression management, and modelling.

Chapter 2

Research aim, objectives, and questions

The thesis is part of work package 3 (WP3) in the ELDORADO research project founded by the Innovation Fund Denmark. The ELDORADO project's purpose was to explore and provide Danish municipalities with new opportunities and solutions to prevent undernourishment among older adults. WP3 aimed to target the future generations of older adults living at home. The current generation of older adults are already more accustomed to and more skillful in using IT systems than previous generations [40], and this knowledge of IT systems will only become more elaborate as today's children grow old. Thus, WP3 aimed to promote well-being in a meal context with a specific focus on how this can be achieved using the opportunities that IT provide.

Guided by WP3's purpose and ambition, the research presented in this dissertation aims to develop an innovative IT prototype promoting healthy meal practices among future generations of older adults living at home in Denmark. The objectives were to (1) identify one or more scenario(s) in which technology can help older adults obtain or maintain habits ensuring a sufficient dietary intake, (2) design and implement an IT prototype that accommodates older adults' needs and preferences in the identified scenario(s), and (3) to evaluate the prototype.

Objective 1: Identify one or more scenario(s) in which technology can help older adults obtain or maintain habits ensuring a sufficient dietary intake

The initial studies focused on getting better insights into the various groups of older adults and in what context meals were consumed. When the PhD work started, an ethnographic study [18] had already started collecting interviews from home-living older Danes across the country, and this qualitative data set was used as the basis for retrieving insights. More specifically, the following research questions were asked:

Q1: What method can segment the behavior of home-living older adults in Denmark captured in qualitative interviews about daily meal practices?

Q2: Which elements of older adults' behavior contribute to healthy, positive meal experiences, and which indicate risk of malnutrition?

Objective 2: Design and implement an IT prototype that accommodates older adults' needs and preferences in the identified scenario(s)

The approach to identify scenarios involved clustering older adults to map out common behavior. The common behavioral patterns were studied for risk indicators found in malnutrition literature to identify scenarios the prototype should address in future generations. The results of the clustering and the ethnographic study [18] indicated that social interactions during meals were an important part of the older adults' daily meal practices and that a group of older adults with a need to socialize but with limited options to participate in social meals existed. As this group of people ate many meals alone, the solitary meal gained focus as the scenario of choice. Relatively little has been written on the subject. In literature, the solitary meal appeared to be associated with snacking (eating less) rather than a proper meal (eating more) and with necessity rather than pleasure (see Section 1.4). From this point of view, people eating exclusively by themselves will eat smaller and quicker meals and be prone to skip meals. The next objective therefore became to develop an IT solution to enhance the solitary meals in a way that promotes positive experiences and sufficient energy intake for future generations of older adults. With this in mind, the following general research questions emerged at this stage:

Q3: What elements of the solitary meal promote positive experiences?

Q4: How can IT contribute positively to the solitary meal experience?

Objective 3: Evaluation of the prototype

MR display technology can digitally overlay an alternative reality on top of the existing world and thus replace or alter the perception of real external elements, such as the environment, that influence the meal experience. The technology also allows complex social interaction between remote eaters by letting them puppeteer a virtual avatar. A prototype was developed to enhance the solitary meal by letting the eater experience an alternative virtual environment with the avatars of other solitary eaters to allow social interactions. The prototype was in accordance with the last objective in this thesis evaluated, by asking the questions:

Q5: How do the prototype's environmental and social features affect food intake and the subjective meal experience of older adults?

Q6: How does the current generation of older adults evaluate the applied technology?

2.1 The contributions and their relation to research questions

The publication dates of the contributions found in Part II of this thesis differ from the order in which the papers were produced; thus, the contributions are here presented in the order of when they had relevance in the development process regardless of publication date.

Besides the produced papers, an initial workshop was held with two groups of older adults from the Holstebro municipality. The workshop aimed to get initial impressions from the older adults regarding imaginary scenarios of technology usage. The first two workshops raised doubt about whether the older adults could envision the technology scenarios presented to them in text, and additional workshops were therefore canceled. However, the parts of the workshop not concerned with the imaginary scenarios answered some of the research questions, and a summary of the workshop therefore appears in this dissertation.

The following paragraphs outline a short presentation of each paper and the workshop as well as how they address one or more research questions. The relations between contributions and research questions are visualized in Fig 2.1.

Workshop: Included two focus groups that investigated attitude toward specific technological interventions and the practices of older adults in the context of arranging and participating in social meals. The workshop mainly contributed to Q2, but the negative feedback on the technology interventions led to the use of personas (see Section 3.1), justifying the need to ask Q1.

Paper A: Proposes a new computer-assisted method for segmenting ethnographic interview data into user archetypes known as personas. The paper uses data from 20 older adults and compares the novel method's output with existing methods in literature and with manual segmentation. The method was used to cluster the behavior of older adults into common patterns and informs Q1, but the outputted personas inform Q2.

Paper B: Describes the early work of developing the first MR meal experience prototype, which allowed a user to eat real food while experiencing a virtual environment. A formative evaluation of the prototype was performed with six adult participants below age 65 to get an indication of feasibility. The paper exclusively contributes to answering Q4.

Paper C: Presents a formative evaluation of the prototype's second iteration. Together with a card-sorting task, the prototype was used to generate conversation with the seven older participants with mobility impairments about technology acceptance and eating environment preferences. The paper addresses Q3, Q4, Q5, and Q6.

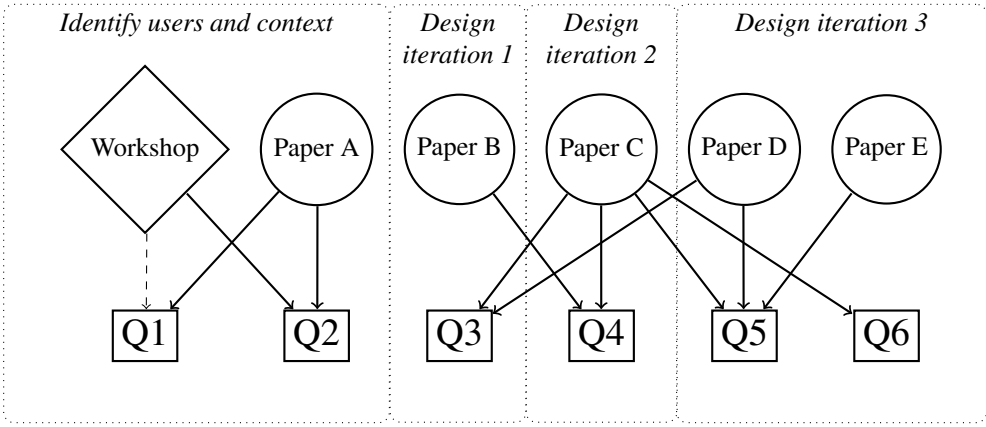

Fig. 2.1: A diagram using arrows to display which research questions that each of the papers and the workshop addresses.

Paper D: Provides the findings of a lab experiment designed to answer Q5, but the findings also contribute to Q3. The paper describes the development of the prototype's third iteration with features that allow social interactions. The results outline the changes in food intake and subjective meal experience of thirty older adults when eating a solitary meal under three conditions: experiencing a virtual environment alone, experiencing a virtual environment together with avatars controlled by two friends, and without MR.

Paper E: Presents an analysis of video recordings of the virtual meal conversations between participants during the experiment described in paper D. The paper provides more details on how the participants experienced the sessions (Q5).

Chapter 4 contains a detailed description of the papers.

Chapter 3

Methods

The previous chapter outlined the aims, objectives and research questions, as well as how each paper contributes to the questions. Since each of the papers got detailed methods sections this chapter will address the overall methodology considerations not already mentioned in the previous chapter, limitations and ethics of the PhD.

3.1 Designing for future generations and the use of personas

Designing for future of generations of older adults makes for a challenge. Even though theories of general relativity outline how it is possible to travel forward in time to ask new generations about the design at the point were they have become old [68]; time travel remains extremely expensive to realise, unpractical (among other reasons because traveling back through time is implausible), and out of the scope of this dissertation. Instead alternative methodologies were investigated that enable design when the target group is unavailable.

Asking the current generation of older adults might be helpful, but could also be misleading. This was attempted as part of a set of initial workshops (see Section 4.1 for a summary). Here four potential IT-based design solutions, all revolved around the use of IT to facilitate meals between unfamiliar older adults, were presented as scenarios to two focus groups of older adults and they were asked to rate each scenario in terms of ease-of-use and appeal. In the results of each scenario a large group of the older workshop participants always marks the scenarios as difficult and repulsive. One of the scenarios was a presentation of the Skype-meal to which one of the workshop participants replied by referring to the screen as a dead thing. This response was in part triggered by not seeing a need for the IT solutions (see Section 4.1). Asking older adults in risk of undernourishment or with impaired functionality may make the solution more relevant to the participants and this was attempted by recruiting mobility impaired older adults for one study (see Section 4.4), but the participants still displayed a low acceptance. This is in line with previous research which has found that older people with poor health is less likely

to adopt IT solutions [76]. Thus, the adoption of the technology should optimally take place before the older person becomes unhealthy. With time older people will be very familiar with IT. Younger generations grow up with social media and use them as part of everyday tasks and it is therefore hard to image the same degree of negative attitudes towards IT solutions as they age and experience health problems. For instance, a recent investigation of the well-being among children and young people in Denmark concluded that this population group spend less time being physically together with their friends compared to previous years, but that virtual contact between them increases without any negative effects to their well-being [144].

Guercio, Marcengo and Rapp faced a similar problem, namely who to ask about their design, when having to design products utilizing futuristic and disruptive technology which the traditional user will have a hard time relating to [71]. They suggested designing for personas which are fictional archetypes created to aggregate and communicate knowledge of the actual users' needs without having to deal with the users' inability to comprehend the technology in question [71]. This strategy was adopted and Paper A outlines how data from ethnographic interviews were used to create the following five personas. The personas are here presented as short descriptions, with the last persona (in bold) being the persona which this thesis targets (due to characteristics and behavior which previous literature highlights as risk indicators of undernourishment (see Chapter 1)):

Self-sustainable commensality husband: He lives with his wife and enjoys life and is at good health. He displays a highly autonomous behavior, thus receiving little help from others, has no impairments, shops independently, and has regular social self-cooked meals often enjoyed with his partner. He has retained smell and taste sensations making him appreciate healthy, tasty food while price is of less importance.

Forthcoming recreational athlete: This older male is highly autonomous with high mobility and thus being socially well-connected. He is of good health and with no significant impairments thus allowing him to exercise regularly and he attends many social activities often related to sports. He shops and cooks his own food at a daily basis. He display a high level of life joy, enjoys tasty food where price is of little importance and finds it appealing to eat with new people.

Regular café guest: This person lives alone and has some health issues, but experience no or little difficulties eating. Spends a significant amount of time at home, but tends to prioritize to eat out usually with other guests at the elderly café. Only cooks when necessary which results in some days with irregular meal pattern.

Anti-tech grandmother: She lives alone and, although she struggles with some health problems, she manages to eat out several times a week, usually at the elderly café. She spends most of her time by herself but engages in social activities from time to time. She has good contacts with her family and has little interest in IT and technology.

Isolated meal-skipping widow: She is living by herself, and, due to health problems and impairments, she never exercises, and the only time she leaves her home is to shop for necessities. Her smell and taste sensations are lowered, and, although she prefers to eat her meals with others, she eats most of her meals alone and rarely engages in social activities. She eats to survive rather than for pleasure, and skipping a meal is not uncommon for her.

The circumstances and needs listed in the description of the isolated and meal-skipping widow persona turned the focus of the PhD towards improving conditions surrounding the scenario of solitary meals. The older adults that is represented by this persona had different skills and levels of interest in IT. However, due to the trend seen in the younger generations, the group of people targeted in this dissertation are the future version of this persona which are assumed to generally have high IT skills and interest. With this said the current generation of older adults was also confronted with the solutions to investigate if they would accept the technology.

3.2 The empirical work and choice of methods

The empirical work performed to investigate the objectives of this thesis are listed in Table 3.1. The work has been done as part of an iterative user-centered design process [185] with focus on prototyping and formative evaluations. From the table it can be observed that 79 users were involved in the design process and evaluation of a developed prototype (paper D and paper E builds on data from the same users). The users included in each study were recruited based on aims of the individual study, but were assumed to resembled the future generation of older adults on a subset of attributes.

The methods applied were a mix between qualitative and quantitative methods (see Table 3.1). Qualitative and quantitative methods were most often used in parallel to analyse independent aspects of the data. As an example, paper B included an interview with the participant together with a hand-eye coordination test in which the number of successful and failed attempts to transfer a ball from one hand to the other was recorded. The qualitative coding was used to map answers to questions (in interviews the answers do not always follow the question asked) and summarize the findings, while the counts of successful and failed attempts were compared between two conditions (statistical analysis was omitted due to small sample size). Thus, the approaches were used to answer different questions. Paper A is the exception. In the study qualitative coding was applied to categorize or quantify non-numerical data (video recordings and interview transcripts) to allow analysis with quantitative methods.

Seen across studies, a pragmatic approach to science has been used where the method which appears best suited to the research problem is applied without adherence to strict philosophical categories [17]. As an example of this diversity, paper C and paper D use methods that typically are applied under different schools of science. Paper D takes the more deterministic perspective [197] and applied an experimental setup designed to investigate whether aspects of the virtual environment (such as the surroundings or social actors) has an impact of food intake and meal experience using only quantitative measures and analysis techniques. Paper C on the other

Paper	Users involved	Data	Analysis
Workshop summary	16	Focus group transcripts Visual analog scales	Qualitative coding Visual inspection
Paper A	20	Interview transcripts	Qualitative coding Subspace clustering
Paper B	6	Success and fail counts Interview transcripts	Count comparison Qualitative coding
Paper C	7	Success and fail counts Interview transcripts Card-sortings	Count comparison Qualitative coding Correspondence analysis
Paper D	30	Food records Questionnaires	Analysis of variance Friedman's rank test Mixed models
Paper E	27	Video recordings	Qualitative coding Count comparison

Table 3.1: Overview of the collected data and methods of analysis.

hand uses the perspective of social constructivism, namely the idea that behavior is influenced by socially constructed norms learned and interpreted through the lens of each individual's subjective experiences [17, 197]. Thus, qualitative methods were applied in paper C to go in-depth with the individual older adult's impressions to uncover the socially constructed norms that motivates behavior in virtual eating environments.

3.3 Limitations

The selected approach for achieving the objectives comes with a set of limitations. Using a futuristic persona description is a simplification and many circumstances surrounding the isolated meal-skipping widow may be completely different in the future. In addition, the developed prototypes were not possible to test on the target group, as the intended user exists in the future and because the current isolated home-living older adult is hard to access (is isolated) and often struggles with illness and mobility problems.

Furthermore, the use of immersive media such as MR systems are not common among many of the included older participant. This entails that the findings may be direct consequences of the novelty associated with experiencing the immersive capabilities of such systems. Lastly, all the studies collected data over a small fixed duration. The findings will tell little of the long term effects that social- and environmental facilitation will have on the prevalence of malnutrition among home-living adults.

The technology applied will set some limitations. At the time of writing, the size of the hardware for immersive media is both heavy and intrusive especially in the eating context, which for instance makes it difficult to drink from an ordinary glass. As the available commercial hardware has not been designed particularly for the older age group, age-related deterioration of eyesight and other senses, reduced mobility, and lowered cognitive ability, may affect the experience. For instance, while the display do allow glasses to be worn underneath it reduces comfort while wearing the headset and glasses with special lenses accommodating the older adults individual decline in eyesight may produce unwanted visual results.

3.4 Ethical issues

Care was taken to ensure that the work conducted as part of this PhD adhered to the General Ethical Principles of the ACM Code of Ethics and Professional Conduct [5]. All participant data were made anonymous immediately after collection to protect confidentiality and avoid potential harm caused by disclosure of the information. This was done by stripping the personal information (name, phonenumber, email etc.) and only using a generated identifier as reference with no dependency to the stripped information. A high level of transparency was strived for and in all cases the participants were informed about the aim of the study, project affiliation, and their right to withdraw at any time. Instructions of the procedure was given beforehand to ensure that the participants felt comfortable. Care was taken to avoid motion sickness, information overload, intensification of experience, and difficulties with reentry into the real world [10]. As an example, the condition of the older adults were monitored as frequently as possible when they engaged in MR experiences, by asking them before, after, and sometimes during the experience, how they felt and aborting if they experienced discomfort. In general, the asking of highly personal questions were avoided to respect privacy and no hospitalized, physically or mentally sick individuals were included in the studies. Instead each study attempted to include participants that approximated the target group on a subset of attributes. In some studies an informant in close contact to the older adults were used to recruit to make sure the participants were capable of making informed decisions and that they were not unduly pressured to cooperate with the research request. In general it was considered very important to create a relaxed atmosphere in which both the researchers and the participants felt at ease.

Chapter 4

Summary of workshop and included papers

4.1 Workshop

Motivation

The first part of the PhD process was an investigation of the problem field. To gain some idea about who the undernourished older adult was and how their practices differ from others an ethnographic study was performed with twenty-two older participants living in different parts of the country [18]. One of the findings of the ethnographic study was that social factors are a large part of older adults' positive meal practices [18]. However, little was known about how the older adults engaged in social meal activities at the time and therefore a workshop was arranged with the aim of finding out how this group of people initiate social meals and whether IT could aid in this process.

Since the work was never published an extended summary will be included with details and findings of the workshop.

Methods and materials

Two focus groups with eight older adults in each (n=16) were held in a rented room above the café, det gode køkken, in the city of Holstebro. The room had all necessary facilities such as a projector, a whiteboard, chairs and tables which were arranged to allow all involved to sit in a ring around the tables. A dictaphone was put in the center table to document the findings of the focus groups. Demographics were collected through a written form, but one female participant did not fill it (thus, we only report demographics from fifteen participants). The groups were recruited among guests of the café and consisted mostly of female participants (female=12) and

the group members were aged between 69 and 81 years. The marital status of the participants were a mix between married (8), divorced (2) and widowed (5). The BMI[1] of the participants showed that the majority of participants were overweight (8) or normal weight (6), while a single person was underweight.

After a presentation round we opened the focus group by asking the participants to use ten minutes to plan a dinner for two to four persons on a weeknight next week. When the participants were ready we asked activity-oriented questions [35], such as *where the dinner should be held? Who they choose to invite? and how they would invite them?* Afterwards we inverted the role of the participants and asked *what factors are important if you are to respond positively to an invitation for dinner?*

A ten-minute break was held and then a headline of a new paper article was shown to the participants with a headline stating that more and more elderly people feel lonely. The headline was used to create a context for the next question: *What factors would make it more appealing to invite and eat with a stranger?* In one group the participants were asked to write their answers down on a note to discuss them afterwards, but we changed this for the second group to a discussion with suggestions written on the whiteboard.

The last part of the workshop presented four scenarios to the older adults in which IT facilitates contact between meal-partners that are unfamiliar to one another. The scenarios were developed to be as short as possible while still conveying the principle to the older adults. The participants were then asked to rate the scenarios on two polar axes: Appealing-Repulsive and Easy-Difficult (to perform). The four scenarios are written below, all starting with *you would like to have company for dinner during the week...*

...You visit the website of the local café targeting older customers and specify a time and include a description of yourself. You recieve a SMS with a potential meal-partner together with a time and place for your dinner. Besides this you receive a subject which you can start to talk about. (Scenario 1)

...You visit the website of the local café targeting older customers and search the descriptions given by café guests who wish company. You write a message to the guests you find most appealing and together you agree on a time and place to have you dinner together. (Scenario 2)

...You visit the website of the local café targeting older customers and are put in contact with meal-partners. After the dinner you have the option to visit the website again and give recommendations to your meal-partners, which can be viewed by other users. (Scenario 3)

...You visit the website of the local café targeting older customers and are put in contact with a

[1] BMI is calculated by the formula $BMI = \frac{weight}{height^2}$ [211] and the categorization is done in accordance with the scheme

$$\begin{cases} underweight, & \text{if } BMI < 18,5 \\ normal, & \text{if } 18,5 \leq BMI < 25 \\ overweight, & \text{if } 25 \leq BMI \end{cases}$$

former guest who now is in the hospital and wish for company. You are put in contact through Skype and eat your dinner in front of the computer while you talk through video and sound. (Scenario 4)

The older participants were then debriefed and thanked for their participation before the groups were dissolved.

The recordings were later transcribed and the answers summarized.

Findings

Hosting a dinner: The arrangements had common trends across both focus groups. The majority of participants (14) would have the dinner at home, while a few (2) would invite guests to a restaurant. None in the second focus group arranged to eat out and when asked why the responses pointed to the small number of people they would invite on a weeknight (when going to a restaurant you invite more people) and the high expenses associated with eating at a restaurant. The older adults would typically invite between 1 and 4 people on a weeknight, which were significant other (1), friends (6), colleagues (1), neighbours (3) or family (5). The meal would for the most part consist of traditional Danish dishes (e.g., mashed potato with bacon, fried pork with parsley sauce, roasted eel, pork tenderloin in cream sauce), the exceptions being local specialities (clipfish, according to the participant a speciality in the Northern part of Jutland) and Mexican foods (Tacos with beef). Dessert were often included in their descriptions with ice-cream and lemon mouse being the most popular choices. Wine and water (water can also refer to sodas in Danish) were common beverages to accompany the meal. The most common way to invite guests were through phone calls (8), followed by invitations in person (5). Only younger family members were invited through SMS (1) or instant messaging (1). We specifically asked the first group if sending a letter was an appropriate, but they agreed that a mailed invitation was too formal for a weeknight.

Acceptance of a dinner invitation: A set of factors were discussed in the two groups as being important determinants of their acceptance or polite rejection of an invitation. The first group quickly pointed out the distance to the arrangement (also internally in Denmark) as an determination factor. Expectations about what kind of activities that should happen before and after the meal were also determinants of a positive response. As an example, several of the participants disliked the idea of attending a party where one was expected to dress up or dance all night. A male participant also highlighted expectations for the food served at the arrangement to be a determinant for his acceptance. The consensus in the second group was that if somebody is kind enough to invite you the invitation should be accepted. When asked how they would prioritize invitations if they received two invitations at the same time for co-occurring events, they listed the type of event and relation to the host as determinants. As an example, it was said that rare and personal events such as a wedding or an anniversary would be more important for them to attend than an ordinary visit to a friend. Close relations could both be the reason for accepting and declining an invitation. The participants were inclined to accept the invitation

from a close relation but said the close relations which they had regular contact with would also show a higher degree of understanding if (or even insist that) the participant accepted the invitation of an old acquaintance. A participant also pointed out that the best invitations were those which were spontaneous or given with short notice, as it made the meal more informal and freed the host from spending a long time planning the event.

Factors making it easier to invite and eat with a stranger: In the discussions the participants expressed no wished to have a meal with somebody they knew nothing about and some even refused to take the though any further. A participants said that having a cup of café with the unknown person would be the first step. In the first group the discussion became more about how to engage in conversation with strangers (a preceding step before inviting the person for dinner). Factors such as living close by each other was mentioned by more participants to promote conversation, but one participant pointed out that the culture among house owners might not apply to the owner of an apartment. Similarly, the culture of living in the country was thought to be more open compared to the culture in neighbourhoods close to cities. Attending group activities where mentioned by some of the participants to be the best way to get introduced to new people. This point of view were also mentioned in the second group where one participant said that she would have no problem with inviting all the focus group members for dinner based on her impression until this point even though she did not know them before the discussions started. It was also mentioned by a participant in this group that it would make her more comfortable to dine with somebody unfamiliar if a known person also attended the meal. She explained that she would feel obligated to entertain the unfamiliar person and that sharing this obligation with somebody else would make it easier. Another person highlighted that it would be uncomfortable for the stranger to attend a meal with three or four people that knew each other. The discussion in the second group focused around not having to have met the person before the meal, but that some background knowledge of the person was a minimum requirement. The kind of knowledge required was difficult to define. Several mentioned having the knowledge that they shared a common interest with the person would help. Knowing that the social encounter was appreciated by the invited was enough for some. A scenario was discussed in which the participant paid for the ingredients and students would prepare and eat the meal with the participant to reduce living expenses. One of the participants said that she would not mind this scenario and that it made her think of her own grandchildren. Some also expressed concerns of whether somebody would falsely pass themselves off as being students, referring to a news story about fake domestic helpers. One person said it was considered easier to meet with three-four persons all strangers to each other than inviting a single unfamiliar person for dinner. Another woman said that a meeting among three to four strangers also made her uncomfortable.

Reactions to Scenario 1 and 2: The comments given to scenario 1 and scenario 2 were very similar and thus they are here treated in the same paragraph. Scenario 1 presented a system that would match meal partners based on a set of provided information. Scenario 2 was a system that allowed the older adults to create and browse the other users profiles to send dinner invites to each other. The majority of responses from both groups to each of the scenarios were negative. Many of the participants talked about the group of people that would have a need for this as

somebody else and one expressed her annoyance with people using mobile phones all the time. In both groups participants commented on scenario 2 and said that it was for younger people. When asked to elaborate, the answer was that younger people are more curious, open to new relations while when you reach a certain age you have enough in the people you already know. Not every participant was as dismissive. One of the older males said that it was not a need now, but if he were alone or became alone in the future, it might be a possibility to use a system similar to scenario 1. A female participant in the first group was more enthusiastic than any of the other participants. She explained that she had a hard time talking to strangers and that using either scenario 1 or scenario 2 would be an easier method for her to engage with people she did not know. Scenario 2 generally more acceptable than scenario 1 because it provided the participants with some details about potential eating partners and gave them a choice of who they wished to share a meal with. However, when inspecting the ratings of appeal and perceived ease of use in Fig. 4.1 and Fig. 4.2 it can be seen that when answers were given individually, not all found the two scenarios unappealing. Seven of the participants in the workshop found both scenarios to be more appealing than repelling. Most of the participants imagined that the solutions of both scenarios would be rather difficult to use.

Reactions to Scenario 3: All the participants in both groups responded negatively to the scenario in which they got to rate a meal partner after the meal was over. They compared it with rating services for companies. A female participant summarized the overall attitude towards the scenarios, by stating that even though you had a negative experience with the person it does not mean that somebody else would. The scenarios lack of appeal were also observable in the individual ratings (Fig. 4.3) with only three of the participants in the workshop found it more appealing than repelling. Most of the participants also imagined this scenario to be difficult for them to operate.

Reactions to Scenario 4: This scenario presented the possibility of contacting sick or otherwise home-bound peers through the use of a VOIP system. The general opinion expressed in the first group were more positive compare to the opinions expressed in the second group. A participant in the first group would use the system if it would be helpful to a family member or a friend (not a stranger) even though she though it sounded unpractical to use while eating. Others in the first group said they did not have the knowledge to use a VOIP system, while others said it was easy to learn and that they had used such a system to keep in contact with family or friends traveling abroad. One participant from the first group returned to her point the system being unpractical in the eating situation and that the meal would not be shared (not eating the same dish and no smell from the other's meal) and suggested that it should be used before and/or after the meal. Another person responded by saying she thought it would be fun and a good place to exchange food recipes. In the second group the immediate response to the scenario was a participant that said the scenario was boring, but good enough for talking with family traveling abroad. Several participants concurred with this statement and elaborated by saying that talking over a VOIP system would not be the same as talking face to face. One participant pointed out turn-taking in the conversation as being different and another referred to the screen in a VOIP system as an obstacle and a "dead thing". It was also pointed out that

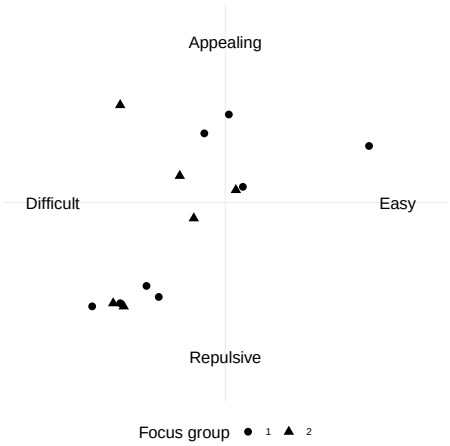

Fig. 4.1: Scenario 1 ratings of appeal and perceived ease of use. Missing ratings from two participants of the second focus group.

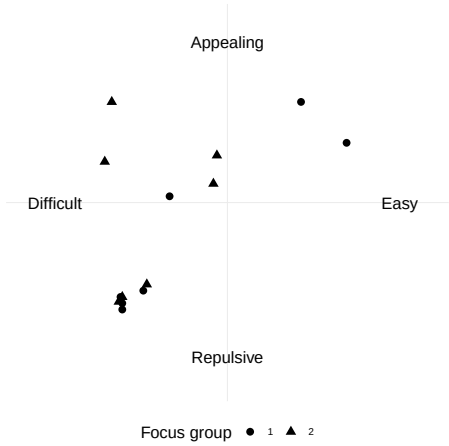

Fig. 4.2: Scenario 2 ratings of appeal and perceived ease of use. Missing ratings from one participant from each focus group.

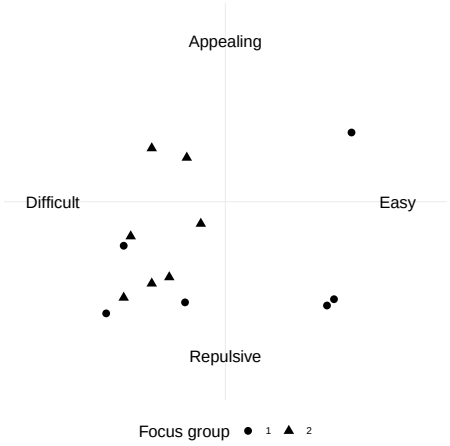

Fig. 4.3: Scenario 3 ratings of appeal and perceived ease of use. Missing ratings from two participants of the first group and a single participant from the second group.

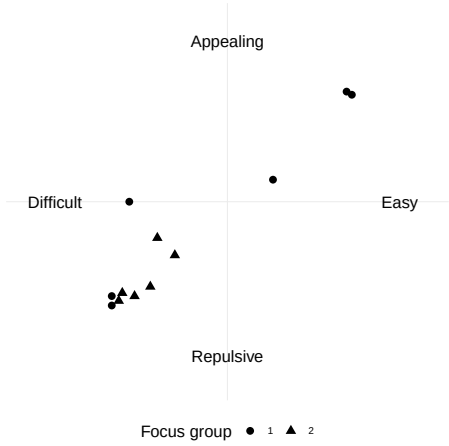

Fig. 4.4: Scenario 4 ratings of appeal and perceived ease of use. Missing ratings from two participants from each focus group.

eating in front of a computer would be poor table manners. The individual ratings of appeal displayed a repulsive attitude towards the scenario from the majority of participants (Fig. 4.4). As indicated by the general discussion in the groups only the members of the first group found it appealing. Interestingly, there also appear to be a clear correlation between how easy the participants believe the system is to operate and how appealing the scenario is. It could be that the ones finding the VOIP solution appealing also are the people who have more experience with using such a solution already.

4.2 Paper A - Creating user models for persona development from qualitative data

Motivation

An essential part of the performed ethnographic study was a set of interviews with the older participants about their daily dietary routines [18]. To segment and summarize the behavior of the interviewed older adults the concept of personas was used. Personas are a set of fictitious user descriptions used in software development to remind the software designers of the diversity of the (potential) user-base [66, 153]. However, a range of methods exists for creating personas based on user-data with different benefits and drawbacks. In this study, we developed a method which enables semi-automated segmentation of the users and addresses drawbacks of existing persona creation methods.

The proposed method and existing alternatives

We proposed to replace the segmentation step of an established persona creation method (Goodwin's method [65]) with a subspace clustering algorithm named density-based optimal projective clustering (DOC). The idea was to delegate the optimization problem of finding the participants with most traits in common to the computer, while leaving the interpretation of interview texts and the writing of persona descriptions to the human operator of the algorithm. The DOC algorithm has properties that makes it helpful in scenarios where the data set has many dimensions and low cardinality, which is often the case with data from qualitative studies. Specifically, the DOC subspace algorithm distinguish itself from alternatives by identifying where the participants group on a subset of the dimensions rather than across ALL dimensions. To evaluate the usefulness of the proposed method it was compared with Goodwin's method performed manually and to a semi-automated alternative named, multiple correspondence analysis (MCA).

Evaluation

A persona designer was hired to create a pool of personas manually. The segmentation step of the manually approach were then replaced by the proposed method and the MCA semi-automated alternative to compare the outcome of the three methods.

Findings

Five of the seven groups found by the persona designer were also returned by the proposed method with it was set to return clusters with many features and low member counts. The two manually found groups unique to the persona designer were not returned by the proposed method as they were not optimal groups. Instead they were included by the persona designers as the similarity of group members on particular dimensions were interesting in relation to the domain being investigated (dietary interventions). The proposed method returned a larger number of clusters (33) compared to the human persona designer (7). This was due to the persona designers tendency to include partial members of the groups which did not have to be similar on all dimensions. A similarity score and a process were proposed that mimics partial memberships.

The proposed method was also able to return clusters that prioritized a high member count by the cost of a set of features. When comparing the relationship between cluster members (how often they appeared as part of the same cluster) the relationship matched the most significant variations found by the MCA approach.

While the proposed method has many benefits such as enforcing a rigorous process, removing some of the labour due to automation, and being easy to convey to lay members of a design team, some limitations remain to be addressed. The proposed method is vulnerable to highly correlated variables and the solution is only an approximation found through sampling. The proposed method may be improved by automating more of the process. Lastly, the paper demonstrated how to obtain a set of personas based on ethnographic interviews from older adults. The resulting personas are summarized in Section 3.1.

4.3 Paper B - Immersive Eating: evaluating the use of head-mounted displays for mixed reality meal sessions

Motivation

The reduction in price of virtual reality hardware open the possibilities to apply the technology in a wide range of domains. The vision of zero calorie virtual meals from Kokiri lab [103], the work of Narumi and colleagues [133, 134] on sensory manipulation, and a set of magazine articles on the creation of extraordinary restaurant experiences [69, 103] inspired the creation of a fast prototype that sought to enable a user to eat while experiencing a virtual environment. The technology could if perfected make the user eat a meal anywhere with anyone. For users with special needs such as the home-bound older adult or hospitalized patient (represented by the isolated meal-skipping widow (see Section 3.1)) it was assumed that the final version of such prototype would be valuable. The paper describes an investigation of the prototype consisting of two cameras mounted on the front of an HMD that enables stereoscopic see-through and allows interaction with real food while the user experiences a virtual environment. The prototype takes advantage of the fact that the user usually observes the environment from a distance while inter-

actions with food are seen up-close by looking down. By mapping the see-through mechanism to the users head-orientation (away from food display the virtual environment/looking towards food enables see-through) eating real food while wearing the HMD was believed possible. But eating wearing an HMD might be unnatural, uncomfortable or impossible and the difficulties of doing so had not been investigated in detail by others.

Methods and materials

The involved participants (n=6) was asked to juggle a single ball from hand to hand for thirty second with and without the HMD (which was locked in see-through mode) to get an indication of the performance loss induced by the see-through capability. Afterwards the participants ate cup noodles, cake, and drank juice privately while wearing the HMD (where see-through was mapped to head-orientation) enabling them to visually explore a virtual park environment. The eating session was followed by a small interview asking questions about the appeal of the interface, how the eating experience compared to ordinary solitary eating, how the food was perceived, if they experienced any problems or sickness, and the degree to which they felt present in the virtual reality.

Findings

The juggling test showed that the interface did decrease performance. The participants began to drop the ball and halved the amount of successful ball transfers from one hand to the other when the task was performed while wearing the HMD. The participants reported mismatch between proprioception and the visual input (due to offset of the camera from the eye position) and other limitations of the system, such as lower field of view, lower framerate, lower resolution and possibility of collision with HMD, which made it harder to eat the food items. Despite this hindrance all participants were able to eat the small meal while wearing the HMD with minimal spilling. The juice and cake were found easier to eat than the noodles.

In general both the food and the virtual environment were described as being consistent, believable with small error (such as stationary clouds in a windy environment and darker color grading of the foods). The quality was sufficient and made one of the participants spontaneously evaluate food-environment congruency, while using the prototype.

All participants found the virtual environment to be the dominant reality and subjective over-estimation of time spend in the virtual environment were given by the majority. All participants said they had an experience of being in the park, but they gave mixed responses when asking about their sense of being in the room. Several of the participants expressed discomfort and slight frustration with the mechanism that switched between realities, but said that it worked in terms of allowing interaction with the food items. Appeal of the system was mixed among the participants.

4.4 Paper C - Where would you like to eat? A formative evaluation of mixed-reality solitary meals in virtual environments for older adults with mobility impairments who live alone

Motivation

Having found that it was possible to eat a meal while experiencing a virtual eating environment (Section 4.3), the next step was to address the limitations of the initial prototype and evaluate the second iteration of the prototype with the intended target group (represented by the isolated meal-skipping widow (see Section 3.1)). A secondary objective of the study was to identify aspects of the eating environment that contribute positively to the solitary meals of older adults.

Method and materials

The second iteration of the prototype replaced the mounted stereo cameras in front of the HMD with an Intel Realsense depth camera on top of the headset. This allowed the food and limbs of the eater to be captured as textured geometry and placed in the virtual environment in a corresponding position. The change was intended to remove the visual-proprioception mismatch and to integrate the food into the virtual experience instead of switching between realities based on head movement. The new prototype also included two virtual environments: a public park and a private kitchen.

A formative evaluation was conducted on this prototype with older adults (n=7) from Holstebro municipality. The recruitment was done through the café, Det gode køkken, and the inclusion criteria were that the participant was above 65 years of age, living alone, and suffered from mobility impairment. The last criterion was included as it is a trait of the target group (personaC) and to find out whether older adults with mobility difficulties would appreciate being able to visit different locations without the hassle of getting there.

To test the participants' handling ability while wearing the HMD, the juggling test from Section 4.3 was performed in which the older adults had to throw a single ball from hand to hand with and without the HMD. Afterwards the participant had to identify three desserts while looking at them through the HMD. Next the participant experienced each virtual environment for one minute each and were asked to select one to eat in based on preference. The participant then ate the desserts while wearing the HMD displaying the chosen virtual environment. As the last element in the evaluation, the participant was interviewed about the eating experience and asked to perform a card-sorting exercise in which dishes written on cards should be placed at pictures of eating environments in accordance with where the participant would prefer to eat the dishes.

Findings

The older adults had great difficulties with the juggling test both with and without the HMD. A decrease was observed in performance when the HMD was worn. The participants also had difficulties with recognizing the desserts viewed through the HMD, which sometimes lead to problems with handling the food correctly. Despite this, all participants were able to eat the desserts.

The participants repeatedly described the atmosphere for their desired eating environment as being "cozy". All participants except one choose to eat in the virtual park environment. The participant that choose the kitchen environment did so due to practical considerations regarding where to sit in the virtual environment. The older adults expressed that they thought about where they would eat in the real world when making their choice. Five of the participants said they felt high engrossed with the virtual environment and five said they were not aware of the real-world surroundings while eating. They critiqued the realism, color scheme and cleanliness of the presented virtual environments.

Results from a card-sorting task showed that surrealistic environments such as floating mountains and undersea restaurant were the least chosen locations, while the terrace, kitchen, fireplace lounge, and restaurant were the most popular locations. The participants appeared to be using a set of considerations to classify where a dish was to be eaten. Classification were based on evaluations of safety, realism, practicality, social acceptability, time of the meal, and indoor-outdoor conditions.

Most participants expressed a negative view on a future use of a perfected version of the prototype. The main reasons of this appear to be a negative attitude towards the use of artificial environments in general, not being able to see the meaning of such a device, impression of a comprehensive installation not fitting for everyday usage, and satiety towards technology.

4.5 Paper D - Eating together while being apart: An experimental study on the effects of computer-generated mixed-reality conversations and virtual environments on older eaters' solitary meal experience and food intake

Motivation

Since social isolation is a factor that correlates with undernourishment among older adults, this paper describes an attempt to add features to the prototype which allow older adults to virtually interact with each other through an avatar-based system and experience a virtual environment together while eating their solitary meals. This prototype may be a strategy which could be applied by the older adult to cope with the boredom associated with solitary meals and to motivate the older adult to prepare a meal and reserve time for eating it instead of rushing or skipping the meal.

A related reason of why the prototype would be useful to older adults is that a range of studies have shown that eating with family or friends tend to increase food intake. Another branch of literature have found that the environment has an influence on the eater (particularly in restaurants) in terms of length of stay and money spent. The main speculation of this thesis is whether experiencing virtual environments and meal companions will have a similar effect as environments and commensal eating in the real world. Thus, and experiment was performed to evaluate the effects the prototype with and without social features compared to a baseline.

Method and materials

The evaluation of the prototype with social features were performed as an experiment. All the participants (n=30) were aged over 65 years and were recruited through the Consumer Panel at Copenhagen University. The experimental design was a within subjects were each participant ate from a dessert buffet by themselves in a room on the same time of the day on three separate days. Each buffet was eaten under one of the following three conditions; eating using the prototype with social features, eating using the prototype without social features and eating without the use of the prototype (baseline). In the condition with social features the participant was asked to bring two friends (also above 65 years) who then similar to the participant ate desserts in separate rooms, while using the prototype.

The prototype placed the user in a photo-realistic living room environment on one of three places around a large rectangular glass table. The social feature made the user appear as a white semi-transparent avatar by mapping the user's head movement to the avatar's head and by displaying the point of view of the avatar to the user. The prototype used by the participant and his or her friends applied a network connection to allow the participant and his or friends to see each others avatars and interact with each other through voice and head movements. The sensor mounted on the headset enabled the user to eat while interacting with his or her virtual meal partners, but since the sensor, due to head movements, was unable to constantly update the visual representation of the food, a user was unable to see a virtual representation of the food of his or her meal partners.

Energy intake as a result of each condition was calculated from the nutritional labeling and weight of the buffet before and after each session. In addition meal duration and a subjective impression was collected of the meal experience through ratings of the participant's internal state (hunger, food desire, mood), food perception (taste, appearence, quality, variation, satisfaction, difficulty of eating), environment perception (presence, congruency with food, stimulation of appetite, atmosphere), and social experience (feeling alone, naturalness of the conversation, sens of personal contact, absorption in the conversation, fun). Energy intake and meal duration was investigated for significant differences between conditions using analysis of variance, while subjective ratings were examined using Friedman's rank test and mixed models.

Findings

No significant differences were found across conditions for meal duration and energy intake. Compared to the baseline (eating without the prototype), eating and using the prototype to experience a virtual environment without social features resulted in the eating environment being rated significantly higher in pleasantness, in liveliness, in ability to stimulate appetite, and in congruency with the served food. The condition also induced significantly higher food quality and taste rating (the latter was borderline) compared to not using the prototype. Using the prototype with social features showed the same significant differences to the baseline, but added significant reductions to ratings of feeling alone and significant higher ratings in positive mood. The conversations were rated by the majority as being enjoyable, absorbing, natural and creating a sense personal contact to the meal partners. The appearance of the food was rated as significantly better in the baseline condition compared to the two other conditions.

4.6 Paper E - Older adults eating together in a virtual living room: opportunities and limitations of eating in augmented virtuality

Motivation

The virtual conversations connecting remote eaters are designed with the hope that they will provide the same benefits of commensal eating. Eating together regularly with social relations creates a stable social structure promotes adherence to social dietary norms, affirmation of social support that may reduce daily stress levels, and could result in a pleasurable experiences that improves mood, self-esteem, and well-being [193]. The study analysed video recordings of the virtual meal conversations from paper D (Section 4.5) to determine what kind of behavior the older adults displayed during the solitary meals and whether these type of meal conversations have the potential to provide the same benefits as commensal meals. Finally, the paper aimed to provide an overview of the design process of the prototype.

Method and materials

Read Section 4.5 as this paper used video recordings from the same experiment. The video recordings of the virtual conversations were captured on each PC, while a tablet placed in front of each participant recorded the bodily behavior of the participant. Due to incomplete recordings, only nine conversations with three participants in each (n=27) were analysed. All recordings were edited into three videos per conversation each showing the virtual conversation from the view point of a participant, while the bodily recordings were placed along the bottom of the edited video as pictures-in-picture. The edited videos were analyzed in ELAN by coding start- and endtimes of utterances, laughter, and specific gestures performed by the participants during

the conversations. Changes in visual attention (between four categories: environment, avatars, food, miscellaneous) were also marked as timestamps by observing the in-eye recordings of each participants using head movement as an indicator of where the participant was looking. After the initial coding, utterances were categorized into topics that were used as the unit of analysis. Quantitative information (durations, counts etc.) were used to describe the behavior of the older adults in addition to the behavioral patterns extracted using the grounded theory approach.

Findings

The findings could be structured in a framework consisting of the elements: context, user, and system. These elements manifest themselves an a set of behaviors, perceptions and interactions expressed in the conversations between the participants.

The context presented by the virtual living room environment and the physical cake buffet was designed to elicit friendly and a private atmosphere. During the conversations the participants spend most time looking at the buffet and each others avatars, while the environment was looked at 1/4 of the time on average. Seating had an influence on environment eye-time. The environment was explored and discussed in the conversations and received more eye-time in those periods of the conversations. A reoccurring discussion was when the participants sought to understand whether they were occupants of the same virtual room or were seated in their own local copies of the room.

The users used verbal expressions indicating that the environment was appealing and aesthetically pleasing. The analysis also highlighted traits of co-presence as users were aware of eachother's presence in the environment. Communication between the users was performed both verbally and non-verbally, often by using deictic gestures with or instead of speech. When gestures were unsupported by the simulation (e.g., pointing) some users used longer descriptions to refer to objects of interest. Gaze was directed towards the avatars 1/3 of the conversation time on average. Laugther occurred frequently (45.8 times on average) during conversations in response to statements and comments and appear to indicate involvement with the stimuli.

The system was often addressed indirectly during the conversations often with an emphasis on the quality of the simulation. The participants looked at the food 1/3 of the time on average, which was reconstructed virtually by a depth sensor and a textured mesh. The noise from the sensor was perceived and described by the participants by the word 'flicker' in six of the nine conversations and statements indicate that the visual quality had an effect on their desire to eat the cakes and their ability to handle small components of the food such as a straw. The participants also encouraged each other to experiment with the limitations of the system, often resulting in laughter.

Chapter 5

Conclusions and perspectives

5.1 Discussion of the contributions in relation to the objectives

The contributions in this dissertation aimed to promote healthy meal practices among future generations of home-living older Danes through the use of IT. The objectives were to (1) identify one or more scenario(s) in which technology can help older adults obtain or maintain habits ensuring a sufficient dietary intake, (2) design and implement an IT prototype that accommodates older adults' needs and preferences in the identified scenario(s), and (3) to evaluate the prototype.

5.1.1 Identified scenario for technology intervention

While the segmentation of older people into personas has been attempted before [210], the work presented as part of this dissertation is unique because it applies a novel persona development method designed to work on small data sets sampled specifically to the design problem. While other methods are designed to work exclusively with quantitative data sets, this method was able to create the five personas from 20 interviews with Danish home-living older adults. The presented method is robust with regard to missing data and data sparsity, which are aspects that other semi-automated persona-development methods struggle with.

The resulting five personas produced using the method developed and evaluated in Paper A segmented the older people into archetypes based on behavior. One of the personas had little pleasure in eating the current meals. A distinct behavioral trait was that the persona enjoyed eating with others but ate nearly all meals alone in her home. Eating every meal alone was considered risky behavior in the light of malnutrition, as solitary meals had been described as smaller [78] and less enjoyable [174] compared to social meals, and solitary meals deny the older adults the benefits of commensality, namely social integration, companionship, and social

support, which aid in upholding healthy dietary habits [193]. The quality of the personas' eating environment at home was unknown, as details of the home environment were not consistently present in the data used for segmentation.

However, eating alone does not necessarily have to be problematic. When asking mobility-impaired older adults about their current eating practices in Paper C, it was found that enhancing the environment in which a solitary meal is eaten can increase the pleasantness of solitary meals. Previous research has found examples of older adults attempting to improve their eating environment through various strategies [94]. The participants in Paper C told us how they appreciated a cozy atmosphere when eating alone. Specific elements in the environment such as a nicely set table, candles and a beautiful and interesting view were highlighted as contributors to a cozy atmosphere.

5.1.2 IT-enhanced solitary meals

As outlined in Section 1.5, a MR interface allows users to handle real food while having a virtual experience, thus enabling optimization of the meal context. This approach is novel and has not been documented in previous literature. At the time of writing, the lack of displays able to convey MR, particularly augmented virtuality (see Fig. 1.4 in Section 1.5), has been a challenge. The studies described in Paper B and Paper C were concerned with the feasibility of eating in MR with a custom prototype. One of the concerns was that discomfort and cybersickness would hinder the desire to eat. While the prototype presented in Paper C still had issues (e.g., visual fidelity of the food), it worked to the level where hand-eaten food could be handled by the older adults, and potential discomfort was reduced to the weight of the headset (with symptoms of cybersickness being rare).

5.1.3 The effects of environmental and social features virtually produced by the prototype

The main study contributing to the evaluation of the prototype was the experiment outlined in Paper D, supplemented by conversational observations in Paper E. The experiment was designed to investigate the effects on food intake and the subjective meal experience when a user ate a solitary meal with and without virtually enhanced meal contexts.

It was found that the use of the virtual living room affected the participants' subjective experience but not the amount of food eaten. The virtual living room was implemented to facilitate a friendly and private atmosphere, and the results of the experiment confirmed the design choices. The environment was rated by the participants as being pleasant and having a more energetic and pleasant atmosphere. It was also rated as a more appropriate location for eating the served cakes. The virtual environment also increased the participants' reported level of appetite (however, this did not lead to an increase in food intake). Notably, the virtual environment also caused the participants to rate the food as having a higher quality. This last effect might be explained by a halo effect [187], where the positive evaluation of the environment influenced

the evaluation of the food. One possibility is that the halo effect is a generalization of previous experiences in which good foods have been served in fine surroundings. The eating environment has previously altered the ascribed properties of the food. For instance, altering the theme of a restaurant leads to an alteration of the perceived ethnicity of the served food [12], and the same foods were rated as more acceptable in the 4-star restaurant than in the institutionalized setting [53]. These findings are an indication that a virtual eating environment has an impact on how the food is experienced [177], and this has implications for discussion on the ecological validity of immersive technologies [2, 7].

Adding the possibility to socially interact through avatars did not result in significant changes in the amount of food consumed. The experiment in Paper D therefore failed to find any social facilitation of eating similar to the study by Bellisle et al. [13]. However, the found reduction of feelings of being alone and the resulting positive change in mood following the virtual meal sessions may indicate that the prototype is able to facilitate some of the important social components of commensality, as pointed out by Vesnaver and Keller [193]. In particular, the component of companionship, described as "enjoyable interactions and shared activities with others that result in well-being and intimicy," appear to be possible through the avatar-based meal interactions [193]. This is further documented in Paper E, which systematically observed that laughter occurred frequently in avatar-based conversations among meal partners using the system. Previous research characterizes laughter as non-verbal communication [151] but also as a result of a feeling of joy, pleasure, or nonseriousness [30]. Laughter has been found to be 30 times more frequent in social compared to solitary situations [152]. Thus, the frequent use of laughter among the meal partners also points to a system that is able to induce a sense of co-presence because the users behave as they would in social settings. Another observation supporting this is that the participants were so engaged in the conversations that they used gestures such as waving and pointing, even though they were not captured and transmitted by the system to their meal partner.

5.1.4 Technology acceptance of the current generation of older adults

While the future generation of older adults was the target group for this dissertation, I dedicated effort to examining how the current generation thought of the developed prototype. Previous research has found age to negatively correlate with acceptance of new technologies [75]. In contrast to recent studies, which found that attitude did not hinder the adoption of immersive VR headsets [89, 161], this study's findings were that the current generation of older adults had little intention to use a perfected version of the prototype in their homes (Paper C).

5.2 Emerged research questions and future perspectives

With the unexpected discovery that food intake was unaffected by virtual social and environmental enhancements a set of new questions are introduced.

Firstly, one might ask whether the aspects of the experiment not related to the system could have influenced the food intake. It is for instance known that non-eating observers can have a negative effect on an eaters intake [78]. During the experiment voice communication was used and the participants were instructed that researchers would be listening in on their conversations to know when the meal was over. More systematic experiments could determine whether an audio-only observer is enough to moderate food intake.

Secondly, it would be relevant to ask whether limitations of the system could be responsible for the unexpected results? As an example the missing feature of being able to see the food of meal partners might have influenced the food consumption. In Paper D it was proposed that modelling is so deeply rooted that the participants compensated with verbal cues instead of the missing visual cues, making the awareness of food consumption unnaturally high limiting the odds of over or underestimation. On the other side previous research has found discussions of the food to be common during social meals [126] and thus what was observed during the virtual meals might be completely normal behavior. As no condition was included in the experiment that allowed observation of non-virtual social meals it is hard to conclude and thus future studies should attempt to compare real and virtual social meals.

On the other hand if one were to assume that the results found by the experiment were unbiased and valid, would the use of virtual meal conversations have any relevance, as it was not able to increase food consumption? The experiment described in Paper D only investigated the immediate effect in food intake of a single meal. Vesnaver and Keller outlined social integration, companionship and social support to be mechanisms which over time mitigates undernourishment [193]. As the work in both Paper D and Paper E indicate that at least one of these mechanisms (companionship) can be facilitated through virtual meal conversations, future studies should attempt to document the long term effects of virtual meal conversations on food intake. Especially the effects that positive emotions have on food consumption as this area in general is under-researched [56].

Environmental facilitation of eating is the term used in this dissertation to refer to the idea that the eating environment can influence the amount of food consumed by the eater. More emphasis should be put on clarifying which external factors that affect food intake and why. The work in this dissertation found that the environment was evaluated positively and even influenced the perceived food quality, but despite evidence of an enhanced experience no significant changes were seen in the amount of food consumed (see Paper D and Paper E). Findings from the interviews in Paper C outlined how activities in the environment can capture the attention of the eater and distract him or her from the sensations of the food. Future studies should investigate whether environments better equipped to engage the user will result in significant changes to food intake and how these compare to e.g. eating while watching television. Similarly, the work in this dissertation investigated virtual environments, which were meant to create a cozy atmosphere and thus bring the eaters in a better mood (arousal and emotion) or making them stay longer in the environment (time extension). Further studies could investigate how a virtual environment can use sensory impressions or learned behavior to stimulate appetite to increase food intake.

Finally, the work presented here demonstrated that older adults can enjoy themselves while being immersed in a virtual meal experience. However, it is still unknown whether these positive emotions will be enough to motivate the older group to return to the virtual meal conversations. As all the setup, such as calibration and establishing connection between clients, were hidden for the older participants in the studies, more effort is need to eliminate these barriers to allow this group of people to enter the virtual experience effortlessly.

5.3 Concluding remarks

Some may find this dissertation provocative. It proposes the idea of immersive eating which may resemble nightmare scenarios depicted in movies such as *The Matrix (1999)* [199] and *Surrogates (2009)* [130], where people outlive their lives in a simulation while being physically pacified and isolated. In addition, this dissertation proposes to augment the meal ritual with more technology, even though it has been found that mobile phone use at the dinner table lowers enjoyment of social interactions [50]. It is fully understandable that these scenarios may awaken feelings of concern among the readership. Even the greatest tech leaders and scientists are concerned about the consequences that new technologies might bring [99, 157, 196].

Seen from a positive perspective, immersive technologies, such as MR, have the potential to allow face-to-face communication to occur between two or more people without them being physically co-located. This feature could solve many problems relevant today. The most common examples are problems associated with transportation, such as commute lines on the highways and CO2 emission during travel. The concept of virtual meetups is already widely accepted by today's younger generations [144], a tendency which has emerged with the popularity of certain games and social media [203]. While one might have concerns about younger people immersing themselves for hours in these technologies, due to the duties they have in real life, the same concerns are not linked to the older adult retired with impairments. If the older adult, despite impairments or illness, is able to perform the activities he or she values (which commonly include filling out a social role or identity, building or maintaining relationships, and enjoying oneself, according to the World Health Organization [212]) through the use of immersive technologies, these tools will be invaluable for that individual. Even though the technology only recently has become affordable and widely available, the use of VR has already yielded some positive stories such as allowing terminally ill children to visit virtual representations of places they are unable to visit [59] and enabling older adults suffering from dementia to revisit places of the past [160].

In this work, I propose using immersive technologies during solitary meals which is a different situation compared to the distracting nature of mobile phone usage in the company of others [50]. Meals are often described as rituals because the behavior associated with food consumption is regulated by shared rules or conventions formed over time [113]. Utilizing technology during meals is novel, it violates the established rules and it is the cause of opposition that may be more pronounced among the oldest group members, as they have performed the meal rituals the longest without the same amount of technology influence experienced to-

day. The modern use of technology in daily activities may provide the coming generations of older adults with an open attitude toward technology use during meals and thus neutralize any controversy that may be associated with the proposals outlined in this dissertation.

Chapter 6

References

[1] "IT," in *A Dictionary of Physics*, 6th ed. Oxford University Press, 2009.

[2] I. N. S. K. Andersen, A. A. Kraus, C. Ritz, and W. L. Bredie, "Desires for beverages and liking of skin care product odors in imaginative and immersive virtual reality beach contexts," *Food Research International*, vol. 116, 2018. [Online]. Available: http://dx.doi.org/10.1016/j.foodres.2018.01.027

[3] K. M. Appleton, C. Dinnella, S. Spinelli, D. Morizet, L. Saulais, A. Hemingway, E. Monteleone, L. Depezay, F. J. Perez-Cueto, and H. Hartwell, "Consumption of a high quantity and a wide variety of vegetables are predicted by different food choice motives in older adults from France, Italy and the UK," *Nutrients*, vol. 9, no. 9, pp. 1–18, 2017.

[4] M. Arvanitakis, P. Coppens, L. Doughan, and a. Van Gossum, "Nutrition in care homes and home care: Recommendations - a summary based on the report approved by the Council of Europe," *Clinical Nutrition*, vol. 28, no. 5, pp. 492–496, 2009. [Online]. Available: http://dx.doi.org/10.1016/j.clnu.2009.07.011

[5] Association for Computing Machinery, "ACM Code of Ethics and Professional Conduct," Tech. Rep., 2018. [Online]. Available: https://www.acm.org/binaries/content/assets/about/acm-code-of-ethics-and-professional-conduct.pdf

[6] J. N. Bailenson, J. Blascovich, A. C. Beall, and J. M. Loomis, "Equilibrium Theory Revisited: Mutual Gaze and Personal Space in Virtual Environments," *Presence: Teleoperators and Virtual Environments*, vol. 10, no. 6, pp. 583–598, 2001.

[7] R. G. Bangcuyo, K. J. Smith, J. L. Zumach, A. M. Pierce, G. A. Guttman, and C. T. Simons, "The use of immersive technologies to improve consumer testing: The role of ecological validity, context and engagement in evaluating coffee," *Food Quality and Preference*, vol. 41, pp. 84–95, 2015. [Online]. Available: http://dx.doi.org/10.1016/j.foodqual.2014.11.017

[8] A. M. Beck, K. Damkjær, and S. F. Simmons, "The relationship between weight status and the need for health care assistance in nursing home residents," *Journal of aging research and clinical practise*, vol. 1, no. 2, pp. 173–177, 2012.

[9] A. M. Beck and L. Ovesen, "Body mass index, weight loss and energy intake of old Danish nursing home residents and home-care clients," *Scandinavian Journal of Caring Sciences*, vol. 16, no. 1, pp. 86–90, 2002.

[10] K.-M. Behr, A. Nosper, C. Klimmt, and T. Hartmann, "of Ethical Issues in VR Research," *Presence*, vol. 14, no. 6, pp. 668–676, 2005.

[11] C. L. Bell, B. K. Tamura, K. H. Masaki, and E. J. Amella, "Prevalence and Measures of Nutritional Compromise Among Nursing Home Patients: Weight Loss, Low Body Mass Index , Malnutrition, and Feeding Dependency, A Systematic Review of the Literature," *Journal of the American Medical Directors Association*, vol. 14, no. 2, pp. 94–100, 2013. [Online]. Available: http://dx.doi.org/10.1016/j.jamda.2012.10.012

[12] R. Bell, H. L. Meiselman, B. J. Pierson, and W. G. Reeve, "Effects of adding an Italian theme to a restaurant on the perceived ethnicity, acceptability, and selection of foods," pp. 11–24, 1994.

[13] F. Bellisle and a. M. Dalix, "Cognitive restraint can be offset by distraction, leading to increased meal intake in women," *American Journal of Clinical Nutrition*, vol. 74, no. 2, pp. 197–200, 2001.

[14] F. Bellisle, A. M. Dalix, and J. M. De Castro, "Eating patterns in French subjects studied by the 'weekly food diary' method," *Appetite*, vol. 32, no. 1, pp. 46–52, 1999.

[15] S. L. Berry, W. W. Beatty, and R. C. Klesges, "Sensory and social influences on ice cream consumption by males and females in a laboratory setting," *Appetite*, vol. 6, no. 1, pp. 41–45, 1985. [Online]. Available: http://dx.doi.org/10.1016/S0195-6663(85)80049-0

[16] Bigscreen Inc., "Official page of Bigscreen," 2019. [Online]. Available: https://bigscreenvr.com/

[17] T. Bjørner, *Qualitative methods for Consumer Research: The value of the qualitative approach in theory and practice*, 1st ed. Hans Reitzel, 2015.

[18] T. Bjørner, D. Korsgaard, H. Christine, and F. J. A. Perez-cueto, "A contextual identification of home-living older adults ' positive mealtime practices: A honeycomb model as a framework for joyful aging and the importance of social factors," *Appetite*, vol. 129, no. February, pp. 125–134, 2018. [Online]. Available: https://doi.org/10.1016/j.appet.2018.07.005

[19] G. Bohme, "Atmosphere as the Fundemental Concept of a New Aesthetics," 1993.

[20] G. Böhme, "Atmoshere as Mindful Physical Presence in Space," *Building atmosphere, OASE*, no. 91, pp. 21–32, 2013. [Online]. Available: https://www.oasejournal.nl/en/Issues/91/AtmosphereAsMindfulPhysicalPresenceInSpace

[21] E. J. Boothby, M. S. Clark, and J. A. Bargh, "Shared Experiences Are Amplified," *Psychological Science*, vol. 25, no. 12, pp. 2209–2216, 2014.

[22] C. Boulos, P. Salameh, and P. Barberger-Gateau, "Social isolation and risk for malnutrition among older people," *Geriatrics and Gerontology International*, vol. 17, no. 2, pp. 286–294, 2017.

[23] M. H. Braun and A. D. Cheok, "Using Scent Actuation For Engaging User Experiences," in *Proceedings of the 12th International Conference on Advances in Computer Entertainment Technology*, no. 54, 2015.

[24] J. L. Butler, D. M. Tice, A. M. Stillwell, and M. B. Muraven, "When modesty prevails: Differential favorability of self-presentation to friends and strangers." *Journal of Personality and Social Psychology*, vol. 69, no. 6, pp. 1120–1138, 1995.

[25] C. Caldwell and S. A. Hibbert, "The Influence of Music Tempo and Musical Preference on Restaurant Patrons' Behavior," *Psychology and Marketing*, vol. 19, no. 11, pp. 895–917, 2002.

[26] G. Calleja, "Spatial Involvement," in *In-Game: From Immersion to Incorporation*. MIT PRESS, 2014, pp. 73–92.

[27] B. L. Callen and T. J. Wells, "Views of Community-Dwelling, Old-Old People on Barriers and Aids to Nutritional Health," *Journal of Nursing Scholarship*, vol. 35, no. 3, pp. 257–262, 2003. [Online]. Available: http://doi.wiley.com/10.1111/j.1547-5069.2003.00257.x

[28] J. M. D. Castro and E. S. D. Castro, "Spontaneous meal patterns of humans: influence of the presence of other people," *American Journal of Clinical Nutrition*, vol. 50, no. 2, pp. 237–247, 1989.

[29] T. Cederholm, R. Barazzoni, P. Austin, P. Ballmer, G. Biolo, S. C. Bischoff, C. Compher, I. Correia, T. Higashiguchi, M. Holst, G. L. Jensen, A. Malone, M. Muscaritoli, I. Nyulasi, M. Pirlich, E. Rothenberg, K. Schindler, S. M. Schneider, M. A. de van der Schueren, C. Sieber, L. Valentini, J. C. Yu, A. Van Gossum, and P. Singer, "ESPEN guidelines on definitions and terminology of clinical nutrition," *Clinical Nutrition*, vol. 36, no. 1, pp. 49–64, 2017.

[30] W. Chafe, *Importance of Not Being Earnest : The feeling behind laughter and humor*. John Benjamins Publishing Company, 2007.

[31] A. I. Christensen, M. Davidsen, O. Ekholm, P. V. Pedersen, and K. Juel, *Danskernes Sundhed – Den Nationale Sundhedsprofil 2013*. Sundhedsstyrelsen, 2013.

[32] V. I. Clendenen, C. P. Herman, and J. Polivy, "Social facilitation of eating among friends and strangers." pp. 1–13, 1994.

[33] M. Cluskey and N. Dunton, "Serving meals of reduced portion size did not improve appetite among elderly in a personal-care section of a long-term-care community," *Journal of the American Dietetic Association*, vol. 99, no. 6, pp. 733–735, 1999.

[34] E. M. Colletta and J. B. Murphy, "Stroke Patient Handbook," *Memorial Hospital of Rhode island*, 1992. [Online]. Available: http://www.jabfm.org/content/5/4/389.full.pdf

[35] E. Colucci, ""Focus groups can be fun": the use of activity-oriented questions in focus group discussions." *Qualitative Health Research*, vol. 17, no. 10, pp. 1422–1433, 2007.

[36] T. Cruwys, K. E. Bevelander, and R. C. J. Hermans, "Social modeling of eating : A review of when and why social influence affects food intake and choice," *Appetite*, vol. 86, pp. 3–18, 2015. [Online]. Available: http://dx.doi.org/10.1016/j.appet.2014.08.035

[37] A. J. Cruz-Jentoft, "Sarcopenia: Preventable and Reversible," in *Prevention of Chronic Diseases and Age-Related Disability*, J.-P. Michel, Ed. Springer International Publishing, 2019, pp. 47–52.

[38] J. J. Cummings and J. N. Bailenson, "How Immersive Is Enough? A Meta-Analysis of the Effect of Immersive Technology on User Presence," *Media Psychology*, vol. 19, no. 2, pp. 272–309, 2016.

[39] Danmarks Statistik, "Markant flere ældre i fremtiden," *NYT fra Danmarks Statistik*, no. 180, p. 2, 2018.

[40] ——, "Over halvdelen af de 16-74 årige streamer," *NYT fra Danmarks Statistik*, no. 245, p. 2, 2018. [Online]. Available: https://www.dst.dk/da/Statistik/nyt/NytHtml?cid=24592#

[41] J. M. De Castro, "Social facilitation of duration and size but not rate of the spontaneous meal intake of humans." *Physiology & behavior*, vol. 47, no. 6, pp. 1129–1135, 1990.

[42] J. de Castro and M. Brewer, "The amount eaten in a meal is a power function of the number of people present," *Physiology and Behavior*, vol. 51, pp. 121–125, 1991.

[43] J. M. de Castro, "Social facilitation of the spontaneous meal size of humans occurs on both weekdays and weekends," *Physiology and Behavior*, vol. 49, no. 6, pp. 1289–1291, 1991.

[44] J. M. De Castro, "Family and friends produce greater social facilitation of food intake than other companions," *Physiology and Behavior*, vol. 56, no. 3, pp. 445–455, 1994.

[45] ——, "Socio-cultural determinants of meal size and frequency," *British Journal of Nutrition*, vol. 77, no. S1, p. S39, 1997. [Online]. Available: http://www.journals.cambridge.org/abstract_S0007114597000081

[46] J. M. de Castro, "Age-related changes in the social, psychological, and temporal influences on food intake in free-living, healthy, adult humans." *The journals of gerontology. Series A, Biological sciences and medical sciences*, vol. 57, no. 6, pp. M368–M377, 2002.

[47] J. M. De Castro, E. M. Brewer, D. K. Elmore, and S. Orozco, "Social facilitation of the spontaneous meal size of humans occurs regardless of time, place, alcohol or snacks," *Appetite*, vol. 15, no. 2, pp. 89–101, 1990.

[48] C. Divert, R. Laghmaoui, C. Crema, S. Issanchou, V. Van Wymelbeke, and C. Sulmont-Rossé, "Improving meal context in nursing homes. Impact of four strategies on food intake and meal pleasure," *Appetite*, vol. 84, pp. 139–147, 2015. [Online]. Available: http://dx.doi.org/10.1016/j.appet.2014.09.027

[49] A. Drewnowski and W. J. Evans, "Nutrition, physical activity, and quality of life in older adults: summary." *The journals of gerontology. Series A, Biological sciences and medical sciences*, vol. 56 Spec No, no. Ii, pp. 89–94, 2001.

[50] R. J. Dwyer, K. Kushlev, and E. W. Dunn, "Smartphone use undermines enjoyment of face-to-face social interactions," *Journal of Experimental Social Psychology*, vol. 78, no. March 2017, pp. 233–239, 2018. [Online]. Available: https://doi.org/10.1016/j.jesp.2017.10.007

[51] E. Edfors and A. Westergren, "Home-Living Elderly People's Views on Food and Meals," *Journal of Aging Research*, vol. 2012, pp. 1–9, 2012. [Online]. Available: http://www.hindawi.com/journals/jar/2012/761291/

[52] J. S. Edwards and I. B. Gustafsson, "The Five Aspects Meal Model," *Journal of food service*, vol. 19, pp. 4–12, 2008.

[53] J. S. Edwards, H. L. Meiselman, A. Edwards, and L. Lesher, "The influence of eating location on the acceptability of identically prepared foods," *Food Quality and Preference*, vol. 14, no. 8, pp. 647–652, 2003.

[54] O. Ekberg, S. Hamdy, V. Woisard, A. Wuttge-Hannig, and P. Ortega, "Social and psychological burden of dysphagia: Its impact on diagnosis and treatment," *Dysphagia*, vol. 17, no. 2, pp. 139–146, 2002.

[55] European Union, *The 2012 Ageing Report: Economic and budgetary projections for the 27 EU Member States (2010-2060)*, 2012, vol. 2. [Online]. Available: http://ec.europa.eu/economy_finance/publications/european_economy/2011/pdf/ee-2011-4_en.pdf

[56] C. Evers, M. Adriaanse, D. T. D. de Ridder, and J. C. de Witt Huberts, "Good mood food. Positive emotion as a neglected trigger for food intake," *Appetite*, vol. 68, pp. 1–7, 2013.

[57] Facebook, "Official page of Facebook Spaces," 2019. [Online]. Available: https://www.facebook.com/spaces

[58] Fødevarestyrelsen, "Råd om mad når du er over 65 år - supplement til De Officielle Kostråd," 2017. [Online]. Available: http://altomkost.dk/fileadmin/user_upload/altomkost.dk/Publikationsdatabase/Pjecer_plakater_mv/Raad_om_mad_til_borger_65_.pdf

[59] M. Fosco, "VR Gives Terminally Ill Children the Experience of a Lifetime," 5 2019. [Online]. Available: https://www.ozy.com/good-sht/vr-gives-terminally-ill-children-the-experience-of-a-lifetime/94159?fbclid=IwAR0cn-jP6QGTtUamcYFWrAC4SsJkQYi44XSZ_sHYZPupnwp2OlON0e2JAjs#.XNm7aJjaND4.twitter

[60] K. N. Frayn, *Metabolic regulation: a human perspective*, third edit ed. John Wiley & Sons, 2010.

[61] J. M. Friedmann, G. L. Jensen, H. Smiciklas-Wright, and M. A. McCamish, "Predicting early nonelective hospital readmission in nutritionally compromised older adults," *American Journal of Clinical Nutrition*, vol. 65, no. 6, pp. 1714–1720, 1997.

[62] N. K. Fukagawa, L. Wolfson, J. Judge, R. Whipple, and M. King, "Strength is a major factor in balance, gait, and the occurrence of falls," *The Journals of Gerontology*, vol. 50A, no. Special issue, pp. 64–67, 1995.

[63] E. Goffman, *The Presentation of Self in Everyday Life*. Peter Smith Pub, 1959.

[64] ——, *Behaviour in public places: Notes on the social organization of gatherings*. London: Collier-Macmillan Ltd., 1963.

[65] K. Goodwin, "Getting from research to personas: harnessing the power of data," 2002. [Online]. Available: http://www.cooper.com/journal/2002/11/getting_from_research_to_perso.html

[66] K. Goodwin and A. Cooper, *Designing for the Digital Age: How to Create Human-Centered Products and Services*. John Wiley & Sons, 2009.

[67] A. Gorini, E. Griez, A. Petrova, and G. Riva, "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*, vol. 9, no. 30, 2010. [Online]. Available: http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00001504-200801000-00009

[68] R. J. Gott, *Time Travel in Einstein's Universe: The Physical Possibilities of Travel Through Time*. HMH, 2015.

[69] J. G. Gregory, "Using Samsung Gear VR to Revolutionize the Restaurant Experience," *Samsung Insights*, 2015. [Online]. Available: https://insights.samsung.com/2015/11/12/using-samsung-gear-vr-to-revolutionize-the-restaurant-experience/

[70] C. Grevet, A. Tang, and E. Mynatt, "Eating alone, together," *Proceedings of the 17th ACM international conference on Supporting group work - GROUP '12*, p. 103, 2012. [Online]. Available: http://www.scopus.com/inward/record.url?eid=2-s2.0-84870288999&partnerID=tZOtx3y1

[71] E. Guercio, A. Marcengo, and A. Rapp, "How to connect user Research and not so Forthcoming Technology Scenarios – The Extended Home Environment Case Study," *Journal of Social Sciences*, vol. 2, no. 4, pp. 203–208, 2007.

[72] P. Gustafson, "Meanings of place: Everyday experience and theoretical conceptualizations," *Journal of Environmental Psychology*, vol. 21, no. 1, pp. 5–16, 2001.

[73] I. B. Gustafsson, Ostrom, J. Johansson, and L. Mossberg, "The Five Aspects Meal Model : a tool for developing meal services in restaurants," *Journal of food service*, vol. 17, pp. 84–93, 2006.

[74] E. T. Hall, "System Notation Proxemic," *American Anthropologist*, vol. 65, no. 5, p. 1003–1026, 1963.

[75] N. Hauk, J. Hüffmeier, and S. Krumm, "Ready to be a Silver Surfer? A Meta-analysis on the Relationship Between Chronological Age and Technology Acceptance," *Computers in Human Behavior*, vol. 84, pp. 304–319, 2018. [Online]. Available: https://doi.org/10.1016/j.chb.2018.01.020

[76] T. Heart and E. Kalderon, "Older adults: Are they ready to adopt health-related ICT?" *International Journal of Medical Informatics*, vol. 82, no. 11, pp. e209–e231, 2013. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S1386505611000682

[77] F. Heidrich, K. Kasugai, C. Röcker, P. Russell, and M. Ziefle, "roomXT: Advanced Video Communication for Joint Dining over a Distance," *Proceedings of the 6th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)*, pp. 211–214, 2012. [Online]. Available: http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=6240393

[78] C. P. Herman, "The social facilitation of eating. A review," *Appetite*, vol. 86, pp. 61–73, 2015. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S0195666314004590

[79] ——, "The social facilitation of eating or the facilitation of social eating?" *Journal of Eating Disorders*, vol. 5, no. 16, 2017.

[80] C. P. Herman and J. Polivy, "A boundary model for the regulation of eating." *Psychiatric Annals*, vol. 13, no. 12, pp. 918–927, 1983.

[81] C. P. Herman, D. a. Roth, and J. Polivy, "Effects of the presence of others on food intake: a normative interpretation." *Psychological bulletin*, vol. 129, no. 6, pp. 873–886, 2003.

[82] R. C. Hermans, J. K. Larsen, C. P. Herman, and R. C. Engels, "Modeling of palatable food intake in female young adults. Effects of perceived body size," *Appetite*, vol. 51, no. 3, pp. 512–518, 2008.

[83] M. M. Hetherington, "Cues to overeat : psychological factors influencing overconsumption," in *Proceedings of the Nutrition Society*, no. 66, 2007, pp. 113–123.

[84] M. M. Hetherington, A. S. Anderson, G. N. M. Norton, and L. Newson, "Situational effects on meal intake: A comparison of eating alone and eating with others," *Physiology and Behavior*, vol. 88, no. 4-5, pp. 498–505, 2006.

[85] J. H. Hollis and C. J. K. Henry, "Dietary variety and its effect on food intake of elderly adults," *Journal of Human Nutrition and Dietetics*, vol. 20, no. 4, pp. 345–351, 2007.

[86] M. Holst, J. Stage, M. Myrup, H. Rasmussen, and M. Skov, "Pervasive Computing As a Motivation for Improving Food Intake in Hospitals: an Empirical Pilot Study," in *Clinical Nutrition Supplements: Abstracts of the 34th ESPEN Congress*, vol. 7, no. 1. Barcelona, Spain: Elsevier Ltd, 2012, p. 12. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S1744116112700297

[87] D. L. Hotaling, "Adapting the Mealtime Environment: Setting the Stage for Eating," *Dysphagia*, vol. 5, pp. 77–83, 1990. [Online]. Available: https://link-springer-com.ezproxy.library.wur.nl/content/pdf/10.1007%2FBF02412648.pdf

[88] HTC, "Official product page of Vive," 2016. [Online]. Available: https://www.vive.com/us/product/vive-virtual-reality-system/

[89] H. Huygelier, B. Schraepen, R. van Ee, V. Vanden Abeele, and C. R. Gillebert, "Acceptance of immersive head-mounted virtual reality in older adults," *Scientific Reports*, vol. 9, no. 1, pp. 1–12, 2019.

[90] L. Hyldstrup, A. M. Beck, K. S. Bjørnsbo, I. Hessov, J. K. Ingerslev, and A. N. Pedersen, "Ernæring og aldring," *Ugeskrift for Laeger*, vol. 164, no. 49, pp. 5757–5759, 2002. [Online]. Available: http://www.scopus.com/inward/record.url?eid=2-s2.0-0037011211&partnerID=tZOtx3y1

[91] B. E. Insko, "Measuring Presence : Subjective , Behavioral and Physiological Methods," in *Being There: Concepts, effects and measurement of user presence in synthetic environments*, G. Riva, F. Davide, and W. A. IJsselsteijn, Eds. Amsterdam: Ios Press, 2003, pp. 110–119. [Online]. Available: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Measuring+Presence+:+Subjective+,+Behavioral+and+Physiological+Methods#0

[92] C. Jacobsson, K. Axelsson, P. O. Österlind, and A. Norberg, "How people with stroke and healthy older people experience the eating process," *Journal of Clinical Nursing*, vol. 9, no. 2, pp. 255–264, 2000.

[93] H. A. R. Jensen, M. Davidsen, O. Ekholm, and A. I. Christensen, *Danskernes Sundhed - Den nationale sundhedsprofil 2017*. Sundhedsstyrelsen, 2017. [Online]. Available: https://www.sst.dk/da/udgivelser/2018/~/media/73EADC242CDB46BD8ABF9DE895A6132C.ashx

[94] T. Jensen, L. Grønnow, and A. P. Jespersen, "Eating strategies – a qualitative study of how frail, home-dwelling older people in Denmark develop strategies to form meaningful eating situations," *Ageing and Society*, no. May 2018, pp. 1–19, 2017.

[95] Y. Johansson, M. Bachrach-Lindström, J. Carstensen, and A.-C. Ek, "Malnutrition in a home-living older population: prevalence, incidence and risk factors. A prospective study," *Journal of Clinical Nursing*, vol. 18, no. 9, pp. 1354–1364, 2009. [Online]. Available: http://doi.wiley.com/10.1111/j.1365-2702.2008.02552.x

[96] M. J. Kaiser, J. M. Bauer, C. Ramsch, W. Uter, Y. Guigoz, T. Cederholm, D. R. Thomas, P. S. Anthony, K. E. Charlton, M. Maggio, A. C. Tsai, B. Vellas, and C. C. Sieber, "Frequency of Malnutrition in Older Adults : A Multinational Perspective Using the Mini Nutritional Assessment," *Journal of the American Geriatrics Society*, vol. 58, pp. 1734–1738, 2010.

[97] H. H. Keller, R. Goy, and S. L. Kane, "Validity and reliability of SCREEN II (Seniors in the Community: Risk evaluation for eating and nutrition, Version II)," *European Journal of Clinical Nutrition*, vol. 59, no. 10, pp. 1149–1157, 2005.

[98] H. Keller, N. Carrier, L. Duizer, C. Lengyel, S. Slaughter, and C. Steele, "Making the Most of Mealtimes (M3): Grounding Mealtime Interventions With a Conceptual Model," *Journal of the American Medical Directors Association*, vol. 15, no. 3, pp. 158–161, 2014. [Online]. Available: http://dx.doi.org/10.1016/j.jamda.2013.12.001

[99] A. Kharpal, "Stephen Hawking says A.I. could be 'worst event in the history of our civilization'," 11 2017.

[100] J. Y. Kim and H. R. Kissileff, "The effect of social setting on response to a preloading manipulation in non-obese women and men," *Appetite*, vol. 27, no. 1, pp. 25–40, 1996.

[101] S. E. Kimes and S. K. A. Robson, "The Impact of Restaurant Table Characteristics on Meal Duration and Spending," *Cornell Hotel and Restaurant Administration Quarterly*, vol. 45, no. 4, pp. 333–346, 2004.

[102] N. Koizumi, H. Tanaka, and Y. Uema, "Chewing Jockey : Augmented Food Texture by using sound based on the cross-modal effect," in *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, Lisbon, Portugal, 2011, pp. 1–4.

[103] Kokiri Lab, "Project Nourished," 2015. [Online]. Available: http://www.projectnourished.com/

[104] D. v. Krevelen and R. Poelman, "A Survey of Augmented Reality Technologies, Applications and Limitions," *The International Journal of Virtual Reality*, vol. 9, no. 2, pp. 1–20, 2010.

[105] F. Landi, R. Calvani, M. Tosato, A. M. Martone, E. Ortolani, G. Savera, A. Sisto, and E. Marzetti, "Anorexia of aging: Risk factors, consequences, and potential treatments," *Nutrients*, vol. 8, no. 2, 2016.

[106] C. Lashley, A. Morrison, and S. Randall, "My most memorable meal ever! Hospitality as an emotional experience," in *Culinary Taste*. Oxford: Elsevier Butterworth Heinemann, 2004, pp. 165–184.

[107] T. Ledoux, A. S. Nguyen, C. Bakos-Block, and P. Bordnick, "Using virtual reality to study food cravings," *Appetite*, vol. 71, pp. 396–402, 2013. [Online]. Available: http://dx.doi.org/10.1016/j.appet.2013.09.006

[108] J. L. Locher, K. L. Burgio, W. C. Yoels, and C. S. Ritchie, "The Social Significance of Food and Eating in the Lives of Older Recipients of Meals on Wheels," *Journal of Nutrition For the Elderly*, vol. 17, no. 2, pp. 15–33, 1998. [Online]. Available: http://www.tandfonline.com/doi/abs/10.1300/J052v17n02_02

[109] D. J. Lowsky, S. J. Olshansky, J. Bhattacharya, and D. P. Goldman, "Heterogeneity in Healthy Aging," *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, vol. 69, no. 6, pp. 640–649, 2014. [Online]. Available: http://biomedgerontology.oxfordjournals.org/cgi/doi/10.1093/gerona/glt162

[110] J. C. Lumeng and K. H. Hillman, "Eating in larger groups increases food consumption," *Archives of Disease in Childhood*, vol. 92, no. 5, pp. 384–387, 2007.

[111] M. Macht, "How emotions affect eating: A five-way model," *Appetite*, vol. 50, no. 1, pp. 1–11, 2008.

[112] Magic Leap Inc., "Official product page of Magic Leap," 2019. [Online]. Available: https://www.magicleap.com/magic-leap-one

[113] D. Marshall, "Food as ritual, routine or convention," *Consumption Markets & Culture*, vol. 8, no. 1, pp. 69–85, 2007.

[114] D. Marshall and R. Bell, "Meal construction: Exploring the relationship between eating occasion and location," *Food Quality and Preference*, vol. 14, no. 1, pp. 53–64, 2003.

[115] M. F. A. Mathey, V. G. Vanneste, C. De Graaf, L. C. De Groot, and W. A. Van Staveren, "Health effect of improved meal ambiance in a Dutch nursing home: A 1-year intervention study," *Preventive Medicine*, vol. 32, no. 5, pp. 416–423, 2001.

[116] M. K. . Maykovich, "Social Constraints in Eating Patterns among the Obese and Overweight," *Society for the Study of Social Problems*, vol. 25, no. 4, pp. 453–460, 1978.

[117] S. J. McAlpine, J. Harper, M. E. T. McMurdo, C. Bolton-Smith, and M. M. Hetherington, "Nutritional supplementation in older adults: pleasantness, preference and selection of sip-feeds." *British journal of health psychology*, vol. 8, no. Pt 1, pp. 57–66, 2003.

[118] H. L. Meiselman, "The contextual basis for food acceptance, food choice and food intake: the food, the situation and the individual," in *Food Choice, Acceptance and Consumption*, H. L. Meiselman and H. MacFie, Eds. Springer, 1996, pp. 239–263.

[119] J. L. Melton, S. Khosla, C. S. Crowson, M. K. O'Connor, M. W. O'Fallon, and B. L. Riggs, "Epidemiology Sarcopenia," *Journal of the American Geriatrics Society*, vol. 48, pp. 625–630, 2000.

[120] Microsoft, "Official page of AltSpaceVR," 2015. [Online]. Available: https://altvr.com/

[121] ——, "Official product page of HoloLens 2," 2019. [Online]. Available: https://www.microsoft.com/en-us/hololens

[122] Z. Milanović, S. Pantelić, N. Trajković, G. Sporiš, R. Kostić, and N. James, "Age-related decrease in physical activity and functional fitness among elderly men and women," *Clinical Interventions in Aging*, vol. 8, pp. 549–556, 2013.

[123] P. Milgram, H. Takemura, A. Utsumi, and F. Kishino, "Augmented Reality: A class of displays on the reality-virtuality continuum," *Telemanipulator and Telepresence Technologies*, vol. 2351, pp. 282–292, 1994.

[124] M. D. Miller, M. Crotty, C. Whitehead, and A. Care, "Nutritional supplementation and resistance training in nutritionally at risk older adults following lower limb fracture: a randomized controlled trial," *Clinical Rehabilitation*, vol. 20, pp. 311–323, 2006.

[125] A. C. Milne, J. Potter, A. P. Vivanti, and A. Avenell, "Protein and energy supplementation in older people at risk from malnutrition (2009)." *Australasian journal on ageing*, vol. 29, no. 3, p. 144, 2010.

[126] L. Mondada, "The methodical organization of talking and eating: Assessments in dinner conversations," *Food Quality and Preference*, vol. 20, no. 8, pp. 558–571, 2009. [Online]. Available: http://dx.doi.org/10.1016/j.foodqual.2009.03.006

[127] J. E. Morley, "Anorexia and weight loss in older persons," *Journal of Gerontology: Medical Sciences*, vol. 58A, no. 2, pp. 131–137, 2003. [Online]. Available: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12586850

[128] ——, "Nutrition in the Older Person," in *Modern Nutrition in Health and Disease*, 2006, vol. 1, no. 22.

[129] S. Z. Moss, M. S. Moss, J. E. Kilbride, and R. L. Rubinstein, "Frail men's perspectives on food and eating," *Journal of Aging Studies*, vol. 21, no. 4, pp. 314–324, 2007.

[130] J. Mostow, "Surrogates," 2009.

[131] M. Mowe, T. Bøhmer, and E. Kindt, "Reduced nutritional status in an elderly population (> 70 y) is probable before disease and possibly contributes to the development of disease," *The American Journal of Clinical Nutrition*, vol. 59, no. 2, pp. 317–324, 1994.

[132] M. Murer, I. Aslan, and M. Tscheligi, "LOLL io – Exploring Taste as Playful Modality," in *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction*, 2013, pp. 299–302.

[133] T. Narumi, Y. Ban, T. Kajinami, T. Tanikawa, and M. Hirose, "Augmented Perception of Satiety: Controlling Food Consumption by Changing Apparent Size of Food with Augmented Reality," *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 109–118, 2012.

[134] T. Narumi, T. Kajinami, S. Nishizaka, T. Tanikawa, and M. Hirose, "Pseudo-gustatory display system based on cross-modal integration of vision, olfaction and gustation," *Proceedings - IEEE Virtual Reality*, pp. 127–130, 2011.

[135] M. Nawahdah and T. Inoue, "Virtually dining together in time-shifted environment: Kizuna design," *Proceedings of the 2013 conference on Computer supported cooperative work - CSCW '13*, no. January, pp. 779–788, 2013. [Online]. Available: http://dl.acm.org/citation.cfm?id=2441776.2441863

[136] Neurons Inc., "Social Interaction in VR," 2016.

[137] K. A. Nijs, G. De Graaf, F. J. Kok, and W. A. Van Staveren, "Effect of family style mealtimes on quality of life, physical performance, and body weight of nursing home residents: Cluster randomised controlled trial," *British Medical Journal*, vol. 332, no. 7551, pp. 1180–1183, 2006.

[138] M. Nyberg and B. Grindland, "The influence of the room context in the meal experience : examples from a hospital and a nursery," *Journal of food service*, vol. 19, pp. 35–43, 2008.

[139] M. Nyberg, V. Olsson, Z. Pajalic, G. Örtman, H. S. Andersson, A. Blucher, K. Wendin, and A. Westergren, "Eating Difficulties, Nutrition, Meal Preferences and Experiences Among Elderly A Literature Overview From a Scandinavian Context," *Journal of Food Research*, vol. 4, no. 1, p. 22, 2014. [Online]. Available: http://www.ccsenet.org/journal/index.php/jfr/article/view/40276

[140] H. O'Brien and E. Toms, "What is User Engagement? A Conceptual Framework for Defining User Engagement with Technology," *Journal of the American Society for Information Science and Technology*, vol. 59, no. 6, pp. 938–955, 2008.

[141] Oculus, "Official product page of Oculus Rift," 2016. [Online]. Available: https://www.oculus.com/rift/

[142] A. Ödlund Olin, P. Österberg, K. Hådell, I. Armyr, S. Jerström, and O. Ljungqvist, "Energy-Enriched Hospital Food to Improve Energy Intake in Elderly Patients," *Journal of Parenteral and Enteral Nutrition*, vol. 20, no. 2, pp. 93–97, 1996. [Online]. Available: http://journals.sagepub.com/doi/10.1177/014860719602000293

[143] J. L. O'loughlin, Y. Robitaille, J. F. Boivin, and S. Suissa, "Incidence of and risk factors for falls and injurious falls among the community-dwelling elderly," *American Journal of Epidemiology*, vol. 137, no. 3, pp. 342–354, 1993.

[144] M. H. Ottosen, D. Andersen, K. M. Dahl, A.-D. Hestbæk, M. Lausten, and S. B. Rayce, "Børn og unge i Danmark: Velfærd og trivsel 2018," Det Nationale Forsknings- og Analysecenter for Velfærd, Tech. Rep., 2018. [Online]. Available: http://www.sfi.dk/rapportoplysninger-4681.aspx?Action=1&NewsId=4537&PID=9267

[145] C. Paquet, D. St-Arnaud-McKenzie, Z. Ma, M.-J. Kergoat, G. Ferland, and L. Dubé, "More than just not being alone: the number, nature, and complementarity of meal-time social interactions influence food intake in hospitalized elderly patients." *The Gerontologist*, vol. 48, no. 5, pp. 603–611, 2008.

[146] K. Patel and D. Schlundt, "Impact of moods and social context on eating behavior," *Appetite*, vol. 36, no. 2, pp. 111–118, 2001. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S0195666300903854

[147] A. N. Pedersen and L. Ovesen, *Anbefalinger for den danske institutionskost*, 2015.

[148] M. Pierce, *Nutrition Support to Elderly Women: Influence on Diet Quality*, S. Bruchey, Ed. Routledge, 2000.

[149] P. Pliner and R. Bell, "A table for one: the pain and pleasure of eating alone," in *Meals in science and practice: Interdisciplinary research and business applications*, H. Meiselman, Ed. Woodhead Publishing, 2009, pp. 169–189.

[150] P. Pliner, R. Bell, E. S. Hirsch, and M. Kinchla, "Meal duration mediates the effect of "social facilitation" on eating in humans," *Appetite*, vol. 46, no. 2, pp. 189–198, 2006.

[151] R. R. Provine and K. R. Fischer, "Laughing, Smiling, and Talking: Relation to Sleeping and Social Context in Humans," *Ethology*, vol. 83, pp. 295–305, 1989.

[152] R. Provine, "Laughter, Tickling, and Evolution of Speech and Self," *Current Directions in Psychological Science*, vol. 13, no. 6, pp. 215–218, 2004.

[153] J. Pruitt and T. Adlin, *The Persona Lifecycle: Keeping People in Mind Throughout Product Design*. Morgan Kaufmann, 2006.

[154] D. W. Rajecki, R. F. Kidd, D. A. Wilder, and J. Jaeger, "Social factors in the facilitation of feeding in chickens: Effects of imitation, arousal, or disinhibition?" *Journal of Personality and Social Psychology*, vol. 32, no. 3, pp. 510–518, 1975.

[155] N. Ranasinghe, G. Suthokumar, K.-Y. Lee, and E. Y.-L. Do, "Digital Flavor: Towards Digitally Simulating Virtual Flavors," *Proceedings of the 2015 ACM on International Conference on Multimodal Interaction*, pp. 139–146, 2015. [Online]. Available: http://doi.acm.org/10.1145/2818346.2820761

[156] E. W. Rasmussen, "Social facilitation: an experimental investigation with albino rats," *Acta Psychol*, vol. 4, pp. 275–294, 1939.

[157] K. Rawlinson, "Microsoft's Bill Gates insists AI is a threat," 1 2015. [Online]. Available: https://www.bbc.com/news/31047780

[158] M. Redd and J. M. de Castro, "Social facilitation of eating: Effects of social instruction on food intake," *Physiology and Behavior*, vol. 52, no. 4, pp. 749–754, 1992.

[159] E. Relph, *Place and placelessness*. London: Pion Limited, 1976.

[160] G. Rhodes, "How virtual reality is taking dementia patients back to the future," 11 2017. [Online]. Available: https://www.theguardian.com/lifeandstyle/2017/nov/20/virtual-reality-taking-dementia-patients-back-to-future-wayback-vr-film

[161] A. R. Roberts, B. De Schutter, K. Franks, and M. E. Radina, "Older Adults' Experiences with Audiovisual Virtual Reality: Perceived Usefulness and Other Factors Influencing Technology Acceptance," *Clinical Gerontologist*, vol. 42, no. 1, pp. 27–33, 2019. [Online]. Available: https://doi.org/10.1080/07317115.2018.1442380

[162] A. Robertson, "Intel is cutting plans for its Project Alloy 'merged reality' headset," 9 2017. [Online]. Available: https://www.theverge.com/2017/9/22/16351900/intel-project-alloy-vr-merged-reality-headset-reference-design-discontinued

[163] B. J. Rolls, "Aging and appetite," *Nutrition Reviews*, vol. 50, no. 12, p. 422, 1992.

[164] B. J. Rolls, E. T. Rolls, E. A. Rowe, and K. Sweeney, "Sensory specific satiety in man," *Physiology and Behavior*, vol. 27, no. 1, pp. 137–142, 1981.

[165] K. Rook, "The Functions of Social Bonds: Perspectives From Research on Social Support, Loneliness and Social Isolation," in *Social Support: Theory, Research and Applications*, I. G. Sarason and B. R. Sarason, Eds. Springer, 1985, pp. 243–267.

[166] M.-L. Ryan, "Interactive narrative, plot types, and interpersonal relations," in *Joint International Conference on Interactive Digital Storytelling*. Berlin Heidelberg: Springer, 2008, pp. 6–13.

[167] S.-j. Salvy, M. Howard, M. Read, and E. Mele, "The presence of friends increases food intake in youth," *The American journal of clinical nutrition*, vol. 90, pp. 282–287, 2009.

[168] C. Saunders, A. F. Rutkowski, M. v. Genuchten, D. Vogel, and J. M. Orrego, "Virtual space and place: Theory and test," *MIS Quarterly*, vol. 35, no. 4, pp. 1079–1098, 2011.

[169] J. Schilp, H. M. K. R. D, H. A. H. Wijnhoven, E. Leistra, A. M. E. R. D, J. J. V. B. M. D, D. J. H. Deeg, and M. Visser, "High prevalence of undernutrition in Dutch community-dwelling older individuals," *Nutrition*, vol. 28, no. 11-12, pp. 1151–1156, 2012. [Online]. Available: http://dx.doi.org/10.1016/j.nut.2012.02.016

[170] H. Schønau-Fog and T. Bjørner, "'Sure, I Would Like to Continue': A Method for Mapping the Experience of Engagement in Video Games," *Bulletin of Science, Technology & Society*, vol. 32, no. 5, pp. 405–412, 2012. [Online]. Available: http://dx.doi.org/10.1177/0270467612469068

[171] R. Schroeder, "Being There Together and the Future of Connected Presence," *Presence*, vol. 15, no. 4, pp. 438–454, 2011.

[172] T. B. Sheridan, "Defining our terms," *Presence: Teleoperators and Virtual Environments*, vol. 1, no. 2, pp. 272–274, 1992.

[173] K. R. Short and K. S. Nair, "Mechanisms of sarcopenia of aging," *Journal of Endocrinological Investigation*, vol. 22, pp. 95–105, 1999.

[174] B. Sidenvall, M. Nydahl, and C. Fjellström, "The Meal as a Gift — The Meaning of Cooking Among Retired Women," *Journal of Applied Gerontology*, vol. 19, no. 4, pp. 405–423, 2000.

[175] M. Slater, "A Note on Presence Terminology," *Presence Connect*, vol. 3, 2003.

[176] J. Sobal and M. K. Nelson, "Commensal eating patterns: A community study," *Appetite*, vol. 41, no. 2, pp. 181–190, 2003.

[177] X. Song, F. J. A. Perez-Cueto, and W. Bredie, "Protein-Enriched Rye Bread: Good alternative source of high quality protein for older adults," *BakingEurope*, 2018. [Online]. Available: http://www.bakingeurope.eu/innovation-profile-university-of-copenhagen.html

[178] K. Spies, F. Hesse, and K. Loesch, "Store atmosphere, mood and purchasing behavior," *International Journal of Research in Marketing*, vol. 14, no. 1, pp. 1–17, 1997.

[179] Statistics Denmark, "Befolkningsfremskrivning 2018," Tech. Rep., 2018.

[180] N. Stroebele and J. M. De Castro, "Effect of ambience on food intake and food choice," *Nutrition*, vol. 20, no. 9, pp. 821–838, 2004.

[181] N. Stroebele and J. M. de Castro, "Listening to music while eating is related to increases in people's food intake and meal duration," *Appetite*, vol. 47, no. 3, pp. 285–289, 2006.

[182] N. Stroebele-Benschop, J. Depa, and J. M. de Castro, "Environmental Strategies to Promote Food Intake in Older Adults: A Narrative Review," *Journal of Nutrition in Gerontology and Geriatrics*, vol. 35, no. 2, pp. 95–112, 2016. [Online]. Available: http://www.tandfonline.com/doi/full/10.1080/21551197.2016.1173614

[183] P. Suedfeld, "The benefits of boredom: sensory deprivation reconsidered," *American Scientist*, vol. 63, no. 1, pp. 60–69, 1975.

[184] Sundhedsstyrelsen, *Oplæg om ernæringsindsatser for den ældre medicinske patient*, 2017.

[185] The International Organization for Standardization (ISO), "Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems."

[186] D. R. Thomas, "The critical link between health-related quality of life and age-related changes in physical activity and nutrition," *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, vol. 56, no. 10, pp. 599–602, 2001.

[187] E. Thorndike, "A constant error in psychological ratings." *Journal of Applied Psychology*, vol. 4, no. 1, pp. 25–29, 1920. [Online]. Available: http://content.apa.org/journals/apl/4/1/25

[188] H.-H. Tsai, Y.-F. Tsai, H.-H. Wang, Y.-C. Chang, and H. H. Chu, "Videoconference program enhances social support, loneliness, and depressive status of elderly nursing home residents," *Aging & Mental Health*, vol. 14, no. 8, pp. 947–954, 2010. [Online]. Available: http://www.tandfonline.com/doi/abs/10.1080/13607863.2010.501057

[189] United Nations, "World Population Prospects 2017: Key Findings and Advance Tables," Tech. Rep., 2017. [Online]. Available: https://www.compassion.com/multimedia/world-population-prospects.pdf

[190] L. R. Vartanian, C. P. Herman, and J. Polivy, "Consumption stereotypes and impression management: How you are what you eat," *Appetite*, vol. 48, no. 3, pp. 265–277, 2007.

[191] L. R. Vartanian, S. Spanos, C. P. Herman, and J. Polivy, "Modeling of food intake: a meta-analytic review," *Social Influence*, no. April 2015, pp. 1–18, 2015. [Online]. Available: http://www.tandfonline.com/doi/abs/10.1080/15534510.2015.1008037

[192] B. Vellas, Y. Guigoz, P. J. Garry, F. Nourhashemi, D. Bennahum, S. Lauque, and J. L. Albarede, "The Mini Nutritional Assessment (MNA) and its use in grading the nutritional state of elderly patients," *Nutrition*, vol. 15, no. 2, pp. 116–122, 1999. [Online]. Available: http://ezproxy.library.usyd.edu.au/login?url=http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med4&AN=9990575%5Cnhttp://dd8gh5yx7k.search.serialssolutions.com/?sid=OVID:medline&id=pmid:9990575&id=doi:&issn=0899-9007&isbn=&volume=15&iss

[193] E. Vesnaver and H. H. Keller, "Social influences and eating behavior in later life: A review," *Journal of Nutrition in Gerontology and Geriatrics*, vol. 30, no. 1, pp. 2–23, 2011.

[194] E. Vesnaver, H. H. Keller, O. Sutherland, S. B. Maitland, and J. L. Locher, "Alone at the Table: Food Behavior and the Loss of Commensality in Widowhood," *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, vol. 71, no. 6, pp. 1059–1069, 2016.

[195] F. Vetta, S. Ronzoni, G. Taglieri, and M. R. Bollea, "The impact of malnutrition on the quality of life in the elderly," *Clinical Nutrition*, vol. 18, no. 5, pp. 259–267, 1999.

[196] J. Vincent, "Elon Musk says we need to regulate AI before it becomes a danger to humanity," 7 2017. [Online]. Available: https://www.theverge.com/2017/7/17/15980954/elon-musk-ai-regulation-existential-threat

[197] J. C. Vischer, "Towards a user-centred theory of the built environment," *Building Research and Information*, vol. 36, no. 3, pp. 231–240, 2008.

[198] M. von Meyenfeldt, "Cancer-associated malnutrition : An introduction," *European Journal of Oncology Nursing*, vol. 9, pp. 35–38, 2005.

[199] L. Wachowski and L. Wachowski, "The Matrix," 1999.

[200] D. Walker and R. Beauchene, "The relationship of loneliness, social isolation, and physical health to dietary adequacy of independently living elderly," *Journal of the American Dietetic Association*, vol. 91, pp. 300–304, 1991.

[201] B. Wansink, "Environmental Factors That Increase the Food Intake and Consumption Volume of Unknowing Consumers," *Annu. Rev. Nutr*, vol. 24, no. 217, pp. 455–79, 2004.

[202] B. Wansink, C. R. Payne, and M. Shimizu, ""Is this a meal or snack?" Situational cues that drive perceptions," *Appetite*, vol. 54, pp. 214–216, 2010.

[203] A. Webster, "Fortnite's Marshmello concert was the game's biggest event ever," 2019. [Online]. Available: https://www.theverge.com/2019/2/21/18234980/fortnite-marshmello-concert-viewer-numbers

[204] J. Wei, A. D. Cheok, and R. Nakatsu, "Let's have dinner together: Evaluate the mediated co-dining experience," in *ICMI'12*, Santa Monica, California, USA, 2012, pp. 225–228.

[205] J. Wei, X. Wang, R. Peiris, and Y. Choi, "CoDine: an interactive multi-sensory system for remote dining," *Ubicomp 2011: Ubiquitious Computing*, pp. 21–30, 2011. [Online]. Available: http://dl.acm.org/citation.cfm?id=2030116

[206] A. Westergren, P. Hagell, and C. Sjödahl Hammarlund, "Malnutrition and risk of falling among elderly without home-help service — A cross sectional study," *The journal of nutrition, health & aging*, vol. 18, no. 10, pp. 905–911, 2014. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/25470807%0Ahttp://link.springer.com/10.1007/s12603-014-0469-5

[207] H. A. H. Wijnhoven, J. Schilp, M. A. E. van Bokhorst-de van der Schueren, H. C. W. D. Vet, H. M. Kruizenga, D. J. H. Deeg, L. Ferrucci, and M. Visser, "Development and validation of criteria for determining undernutrition in community-dwelling older men and women : The Short Nutritional Assessment Questionnaire 65 þ," *Clinical Nutrition*, vol. 31, no. 3, pp. 351–358, 2012. [Online]. Available: http://dx.doi.org/10.1016/j.clnu.2011.10.013

[208] K. Wikby and A. Fägerskiöld, "The willingness to eat: an investigation of appetitive among elderly people," *Scandinavian Journal of Caring Sciences*, no. 18, pp. 120–127, 2004.

[209] L. M. Wilcox, R. S. Allison, S. Elfassy, and C. Grelik, "Personal space in virtual reality," *ACM Transactions on Applied Perception*, vol. 3, no. 4, pp. 412–428, 2006. [Online]. Available: http://portal.acm.org/citation.cfm?doid=1190036.1190041

[210] B. Wöckl, U. Yildizoglu, I. Buber, B. Aparicio Diaz, E. Kruijff, and M. Tscheligi, "Basic senior personas: a representative design tool covering the spectrum of European older adults," *Proceedings of the 14th international ACM SIGACCESS conference on Computers and accessibility*, pp. 25–32, 2012. [Online]. Available: http://doi.acm.org/10.1145/2384916.2384922

[211] World Health Organization, "Physical status: the use and interpretation of anthropometry," Tech. Rep., 1995.

[212] ——, "World report on ageing and health," Tech. Rep., 2015.

[213] R. B. Zajonc, "Social Facilitation," *Science*, vol. 149, no. 3681, pp. 269–274, 1965.

Part II

Papers

Paper A

Creating user models for persona development from qualitative data

Dannie Korsgaard, Thomas Bjørner, Pernille Krog Sørensen, and Paolo Burelli

The paper has been submitted to the
Journal of User Modeling and User-Adapted Interaction, 2019.

The layout has been revised.

Paper is excluded in this redacted version of the dissertation.

Paper B

Immersive Eating: Evaluating the Use of Head-Mounted Displays for Mixed Reality Meal sessions

Dannie Korsgaard, Thomas Bjørner, and Niels Christian Nilsson

The paper has been published in the
Proceedings of the IEEE 3rd Workshop on Everyday Virtual Reality (WEVR), 2017.

The layout has been revised.

Paper is excluded in this redacted version of the dissertation.

Paper C

Where would you like to eat? A formative evaluation of mixed-reality solitary meals in virtual environments for older adults with mobility impairments who live alone

Dannie Korsgaard, Thomas Bjørner, and Niels Christian Nilsson

The paper has been published in the
Food Research International Vol. 117, pp. 30–39, 2018.

The layout has been revised.

Paper is excluded in this redacted version of the dissertation.

Paper D

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

Dannie Korsgaard, Thomas Bjørner, Pernille Krog Sørensen, Jon Ram Bruun-Pedersen, and Federico J. A. Perez-Cueto

The paper has been submitted to the
Appetite Journal, 2019.

The layout has been revised.

Paper is excluded in this redacted version of the dissertation.

Paper E

The behavior of older solitary eaters engaged in mixed-reality meal conversations

Dannie Korsgaard, Thomas Bjørner, Jon Ram Bruun-Pedersen, and Pernille Krog Sørensen

The paper has been submitted to the
IEEEVR conference, 2019.

Paper is excluded in this redacted version of the dissertation.

ISSN (online): 2446-1628
ISBN (online): 978-87-7210-441-6

AALBORG UNIVERSITY PRESS