Designing Kitchen Technologies for Ageing in Place: A Video Study of Older Adults' Cooking at Home

SANNA KUOPPAMÄKI, KTH Royal Institute of Technology, Sweden
SYLVAINE TUNCER, KTH Royal Institute of Technology, Sweden
SARA ERIKSSON, Stockholm University, Sweden
DONALD MCMILLAN, Stockholm University, Sweden

Assistive technologies can significantly increase older adults' independent living if these technologies are designed to meet their needs and abilities. This study investigates conditions and present possibilities for assistive technology to provide physical and cognitive support to older adults in a specific domestic task, which is cooking a meal at home. The empirical material consists of six video recordings of adults aged 65 and over preparing a meal in their kitchen. The study unpacks the complexity of kitchen tasks, from the physical interactions involved to the temporal and spatial alignment of objects and goals in the kitchen. We focus on a) *Physical manipulation*, such as chopping, opening packages, and moving objects around the kitchen, b) *Organisation and coordination*, including switching, synchronising and monitoring cooking tasks, and c) *Reorchestration and reorganisation* in the form of inserting additional tasks, and rearranging tools and ingredients when adjustments need to be made in the cooking process. The study outlines design principles for operational and organisational interventions to support cooking a meal for independent living. The study concludes with discussing design implications for conversational user interfaces in the kitchen, and the significance of assistive kitchen technologies for ageing in place.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**.

Additional Key Words and Phrases: human-food interaction, kitchen technologies, older adults, cooking, video study

ACM Reference Format:
Sanna Kuoppamäki, Sylvaine Tuncer, Sara Eriksson, and Donald McMillan. 2021. Designing Kitchen Technologies for Ageing in Place: A Video Study of Older Adults' Cooking at Home. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 5, 2, Article 69 (June 2021), 19 pages. https://doi.org/10.1145/3463516

1 INTRODUCTION

Ubiquitous and pervasive systems for the home present an exciting opportunity to improve domestic environments and support the manifold mundane actions conducted therein, such as bathing, cooking or cleaning. While the benefits of such technology can be far reaching, one promising opportunity for such systems is to support the capability of older adults (defined as those over 65 years old) to live in their homes longer, which is called ageing in place [48, 49].

Authors' addresses: Sanna Kuoppamäki, sannaku@kth.su.se, Department of Biomedical Engineering and Health Systems, KTH Royal Institute of Technology, Stockholm, Sweden; Sylvaine Tuncer, sylvaine.tuncer@kcl.ac.uk, Division of Robotics, Perception and Learning, KTH Royal Institute of Technology, Stockholm, Sweden; Sara Eriksson, sara.eriksson@dsv.su.se, Department of Computer and System Sciences, Stockholm University, Stockholm, Sweden; Donald McMillan, donald.mcmillan@dsv.su.se, Department of Computer and System Sciences, Stockholm University, Stockholm, Sweden.

2474-9567/2021/6-ART69 $15.00
https://doi.org/10.1145/3463516

Current assistive technologies for older adults can be categorised as attempting to provide technological support in physical and cognitive tasks, as well as to support their social and emotional well-being [10, 15, 24, 29]. Technologies providing physical assistance have advanced from mechanical and ergonomic support, such as additional hand holds, mechanised can openers and mixers, to assistive robotic technology, such as robots which assist in lifting items or people. Cognitive assistance is currently limited to reminders, either set by the user through direct interaction via a touch or voice interface, or triggered by the environment or actions such as with monitoring technology, timers, and memory aids [50]. Examples of technology meeting social and emotional needs can be seen in a range of research and commercial deployments, from digital picture frames and remote awareness technology, such as the Whereabouts clock and Video Windows [6], to embodied emotional agents [29].

HCI research has investigated older adults as users of assistive technologies [3], active ageing technologies [10], smart homes and kitchen systems [13, 28], robot pets [29], and smart homes outfitted with assistive robots [21]. Technologies providing collaborative support that combine cognitive and physical assistance in the home environment are still very rare. This paper aims to contribute to the design of such technologies. Through detailed analyses of video recordings of older adults' cooking without any assistive technologies, we show the complexities of a particular kitchen task. To help ensure that such assistive technology fits the needs and practices of older adults and achieves the goal of helping them with ageing in place, we present design principles that can be embedded into kitchen technologies.

Many smart kitchen systems have been developed to improve the overall workflows of the cooking process in general [19, 20, 40, 47]. Some kitchen systems have been designed for older adults in particular [3, 4, 13, 28]. Assistive technology for older adults has focused on intelligent mobility aids or sensors in the home environment, mostly overlooking the significance of kitchen activities for the well-being of older adults [5, 22, 31–33, 51]. To complement these approaches, we present aspects of organisation and coordination involved in particular kitchen tasks, and consider the age-specificity of these cooking tasks in the development of design interventions for assistive technologies in the kitchen. The main contributions of our study are:

- An analysis of the complexity of kitchen tasks among older adults
- The categorisation of kitchen tasks under physical manipulation, organisation and coordination of tasks, and reorchestration and reorganisation
- The presentation of design principles for operational and organisational assistance in the kitchen to support ageing in place.

The paper begins by introducing existing research on cooking in the field of human-food interaction, and ageing in place. In the methods section, we present a collection and analysis of video recordings. The results section consists of presentations and analyses of short extracts from the video data. We describe three practices in detail: physical tasks carried out during meal preparation, coordination of the cooking process, and reorganisation around the objects and recipes. This is followed by the development of principles for operational and organisational intervention in the kitchen. Finally, we discuss the implications of our findings for conversational user interfaces and digital kitchen technologies to support ageing in place.

2 BACKGROUND

2.1 Cooking and the Kitchen in Human-Food Interaction

Food production, distribution and consumption have recently attracted growing attention in the field of HCI [7, 8, 16, 34–36]. Cooking is a cross-cultural practice that supports communities by bringing people together, enabling communality, solidarity, and leading to commensality: shared meals and community building [43, 44]. Food practices, including sourcing, storing, producing, tracking, eating and contemplating food [1] can also be considered inspirational, aesthetical, relational and functional.

In human-food interaction (HFI), cooking is a skill that consists of combining, mixing, processing and handling ingredients. Technological support designed for cooking has focused on offering instructional guidance and multimodal feedback on cooking, and supporting social and experiential aspects of cooking with technology [25]. Instructional guidance includes following recipes in the correct order. "Cooking Navi" used multimedia to offer instructional guidance on cooking based on the interpretation of cooking workflows and rescheduling recipe steps [18]. "Smart VideoCooKing" offered instruction for each cooking step by means of personalised videos [12]. "MimiCook" displayed written instructions with video-projection to offer immediate feedback for the person in the kitchen [40], and "Shadow Cooking" guided users with situated, step-by-step information projected onto the ingredients [41].

Representational modalities for giving feedback on cooking have also been developed. These systems include computer-enhanced cooking pans [47], embedded sensors for detecting the thermal information [26], or detecting the skill levels of cooks by tracking their hand and head motions [2]. Both instructional guidance and multimodal feedback on cooking can be useful in guiding the cooking process, handling ingredients, or helping the person adjust the right temperature in cooking. However, adapting these systems to dynamic situations and actions is still difficult [34]. If the system requires too much input from the user, it can be considered distracting [19].

Cooking skills, recipes and techniques are shared with families and networks through informal and formal interactions [44]. Therefore, technology design needs to consider the social, collaborative and experiential aspects of cooking [34–36]. To describe the complexity of cooking together with others, Paay et al. [35] identified three distinct task-related configurations: working on related tasks, working on independent tasks, and working on shared tasks. They also identified four collaboration-oriented actions: observing, checking, helping, and showing [35]. Preparing a meal requires various subtasks that are performed in preparation for the actual food making (e.g., chopping vegetables as a preparation). People perform both independent and shared tasks, and they can collaborate by either helping each other or sharing the task.

Several design solutions for the experiential aspects of cooking have been proposed [4, 7]. Schneider [43] suggested a semantic cookbook inspired by handwritten recipes that are passed down from one generation to another. Davis et al. [9] described a homemade family cookbook, and Terrenghi et al. [45, 46] designed a "Living Cookbook" created from recordings of cooking in order to learn, share and educate others. Social and emotional aspects of cooking were incorporated into "Smart Kitchen" [42] and "Talking Bottle" [4]. These interventions are built on interactions with cooking appliances, digital meal-sharing apps, and the shared experience of cooking together at a distance. Designing food practices as complex, socially and emotionally charged events in everyday life requires cultural awareness and sensitivity towards the traditions and experiences of individuals [11].

Several problems can arise during everyday cooking practices. Cooking and meal preparation are characterised by *uncertainty* in what to prepare for dinner, choosing recipes and making food-related decisions. Interaction with food is often accompanied by *distraction* caused by routines and the day-to-day activities of life. *Inefficiencies* occur in searching for items in kitchen cabinets, and many times the individual's *inexperience* impedes the process of cooking, and people make unhealthy choices due to *lack of nutrition knowledge*. [17]. Maintaining and learning cooking skills are thus essential for the quality of life and well-being of individuals in general, and those of older adults in particular as we address below.

2.2 Cooking and the Kitchen Among Older Adults

Cooking skills are central to older adults' ability to live independently in their own homes. Ageing in place refers to "remaining living in the community, with some level of independence, rather than in residential care" [48, 49]. The purpose is to ensure that older adults can maintain their independence, autonomy, participation and security in their homes. Maintaining and developing cooking skills can contribute to successful ageing [39] and active ageing [10] by lowering the risk of disease and disease-related disability; maintaining high mental and physical function, and enabling continued engagement with life, which includes relations with others and productive activity.

Few studies have designed smart kitchens for older adults [3, 4, 13, 28]. Blasco et al. [3] developed Ambient Assisted Living (AAL) applications to help older adults increase their autonomy in kitchen-related activities. The Smart Kitchen integrates a variety of home technologies (household appliances, sensors, user interfaces), and communication and media (power line, radio frequency) to provide support to older adults at home, in transport and at work, and to increase their social inclusion, communication, and participation in a community. The evaluation showed that users needed training to be able to use the system.

Kosch et al. [28] conducted a qualitative study on the design requirements for smart kitchens and communal cooking for people with cognitive impairments. Cognitive impairments refer to difficulties in learning, remembering information, or making decisions as a result of a health condition, injury or age-related disease. Communal cooking was developed based on collaborative accessibility and joint activities between residents and their instructors in sheltered housing. Cooking was seen as a key activity in the learning process of independent living: work organisation in the cooking tasks, social dynamics of the sheltered living community, supervision of residents and practical concerns on the safety of the cooking procedures. Designing assistance for the kitchen was based on supporting coordination work, including task division between residents and instructors, monitoring ongoing tasks, and organising work.

Healthy ageing and well-being in the kitchen are also associated with maintaining connections with social networks. Brereton et al. [4] developed a messaging kettle that aims to share the experience of cooking at a distance and respond to communicative needs in the kitchen for adults in their 50s, 60s, and 80s. Kitchen technologies that respond to communicative needs at home are considered useful for long-distance families, or individuals who have difficulties maintaining a feeling of connectedness [7].

In summary, kitchen technologies designed for older adults can be seen as *assistive technologies*: they help them maintain their independence, well-being, and physical and cognitive functioning. A wide range of research has been conducted on assistive technologies for older adults and their connection to ageing in place [32]. Studies focus on psychological and socio-emotional design requirements [5], barriers to the adoption of assistive technologies among older adults [51], the effects of assistive technology intervention on older adults with disabilities and their informal caregivers [33], and engaging older adults with dementia in creative occupations [31]. These studies, however, overlook the relevance of the very actions and practices involved in cooking and the kitchen to support ageing in place.

3 METHODS

3.1 Data and Participants

The study reports findings from a qualitative study conducted among older adults (aged 65 and over) in their place of residence, a house or a flat where they either lived alone or with their spouse. The data consist of video recordings of 6 sessions[1] of participants cooking a meal, as well as interviews and informal conversations before and after the cooking session. Each recorded cooking session lasted approximately 60 minutes, and was followed by a 30-minute interview. Participants were recruited through their prior participation in design workshops at the university. An invitation was sent via e-mail to 26 participants, and 6 replied to volunteer: they agreed to be video-recorded while preparing a meal in their kitchen. Four of the participants were female, three were male. Six of the seven participants lived with their spouse. The total data amounted to 4 hours and 40 minutes, with meals varying from meatballs and fish soup to pancakes and meat pie, all starting from raw ingredients.

[1] The data also include one observation of a couple, making the total number of participants 7. While more data collection was planned, we stopped making home visits with our target group during the ongoing pandemic.

In preparation for the observations and recordings, participants were asked to be prepared to make a meal of their own choice in their kitchen. All participants prepared recipes they were familiar with and had prepared before. Participants were not asked to follow a formal recipe; however, they were free to do so. While all participants were experienced in cooking a meal, how often they cooked for themselves and their use of kitchen tools varied between participants. Participants most often cooked for themselves and their spouse.

We recorded the whole cooking session, from ingredient preparation to the meal being plated. Video recordings started when the participants began to arrange objects in the kitchen. During the recording and observation, the participants were invited to narrate or comment on anything that they deemed relevant, from habits to cooking preferences, through recurring problems, personal experience, and their use of technologies of any sort. The observation was followed by a 30-minute, semi-structured interview which was recorded, and it covered the participants' experience of using digital technology, such as smartphone or other mobile technology for communication and information-seeking. These semi-structured interviews provided the researcher with information to contextualise the cooking practices in relation to digital technologies.

3.2 Analytic Approach

The analysis of the video recordings was guided by the principles of the visual content analysis method [27]. This approach aims to unpack practices which are in plain view but also evident: they are seen but unnoticed. While many actions in the kitchen, which is a familiar and intimate environment, are highly routinised, they are also shaped in specific ways according to local contingencies and the unexpectable developments of the situation. We started with an unmotivated approach: instead of defining our focus a priori, we first looked at the data with an open mind, and defined our focus drawing from what emerged from the data. By analysing video recordings of naturally occurring activities in this way, we aim to provide a fine understanding of the most ordinary, but also socially and individually fundamental, practices.

In the first phase of the analysis, all video recordings were watched with the goal of forming a comprehensive overview of the content of the videos, such as the flow of actions, conflicts, and interruptions in the cooking process. In order to focus on age-specificity, we then followed by extracting instances involving fluencies or disfluencies in action due to age-related physical and cognitive skills. We created collections of short (approximately 1-3 minutes) video clips which we collectively analysed in focused data analysis sessions. We focused on participants' actions and skills as part of an overarching activity and in relation to the particulars of the material setting, paying particular attention to the age-specificity of the skills in cooking a meal as described above. In an iterative process over multiple sessions, we categorised these clips under categories and sub-categories, settling with three top-level categories: *Physical manipulations; Organisation and coordination of tasks*; and *Reorchestration and reorganisation.* We created sub-categories based on further detailed analyses of the clips within each main category to distinguish recurrent features and variations. To protect the participants' privacy, they were given pseudonyms, their faces have been blurred in the images extracted from the video data, and all forms of personal details were removed.

4 KITCHEN TASKS AMONG OLDER ADULTS

In this section, we describe the tasks we identified in the data and categorised under three headings: *Physical manipulation; Organisation and coordination of tasks;* and *Reorchestration and reorganisation.* By physical manipulations, we refer to practical and functional tasks such as chopping ingredients or opening packages, drawers and cupboards. Organisational practices cover tasks which aim to coordinate the cooking tasks, such as switching between, synchronising, and monitoring tasks. Reorchestration refers to revising original plans, and readjusting the course of action. Because kitchen tasks are practical actions performed with gestures, movements and sayings, some parts of them are computationally tractable for recognition and segmentation, and atomic for targeted design interventions.

4.1 Physical Manipulation

Our participants provided us with numerous examples of the various ways in which they can use different tools in their kitchens. Even though a majority of tasks were performed with fluency, participants mentioned and sometimes showed us fluencies and disfluencies in actions such as opening packages, using knives, lifting tools, and reaching for items in cabinets. These difficulties could delay or briefly interrupt the ongoing course of action. Some disfluencies were caused by age-related, physiological changes, such as lack of strength, or joint pains, while others appeared to result from the poor quality of the tools and objects themselves. Often these two types of disfluencies were inseparable.

4.1.1 Cutting and Chopping. Our participants were visibly comfortable with, and skilled at, cooking a meal at home. A basic task in cooking those meals was cutting the ingredients into the right shape and size for the recipe. This was a well-practiced and familiar task for our participants and was embodied in the usage of various ingredients and tools. While chopping potatoes, one participant, Martin, demonstrated several examples of such learned skill and familiarity with the tools. Martin quickly chopped his potatoes to size, holding the ingredients steady with the fingers of his left hand and stabilising the chopping board underneath with its heel while using a vertical motion with the hand holding the knife to slice cleanly through the body of the potato. Martin also demonstrated a number of physical manipulations with a knife to turn it to tasks other than simple chopping. By holding the knife so as to be able to lever the blade against his thumb, while keeping ingredients in his other hand, he was able to use the edge of the blade closest to the handle as a peeling knife. In another example, shown in Figure 1, Martin uses the large blade of the knife as a spatula, holding pieces of sliced potatoes against the blade while transferring the ingredients from the chopping board (1.a), into a bowl (1.b).

1.A 1.B

Fig. 1. Martin demonstrating fluency in chopping and peeling

The data also comprise examples of disfluencies in the task of chopping ingredients. Figure 2 is a series of screenshots of the various methods attempted by Emily as she visibly struggles to chop an onion, which will eventually take her a relatively long time. Figure 2.a shows Emily starting to chop the onion in a vertical motion, holding the knife in her right hand and the onion in her left with the heel of her hand controlling the chopping board. She adjusts her hold of both the knife and onion, continues to chop using a sawing motion, while leaning her upper body closer to and over the counter (2.b), and then places her left hand on the knife, adding more pressure on the blade (2.c). Emily's difficulties in chopping this onion can in part be explained by the knife's apparent bluntness, but her limited strength plays a considerable role, according to her own statement that arthritis had made such actions increasingly painful and difficult in the past years.

Fig. 2. Emily tries different methods with the knife when struggling to chop onions

4.1.2 Opening Packages, Drawers, and Cupboards. One aspect of the organisation of domestic space is the nesting of objects within others, be that clothes within closets or, as in this case, tools and ingredients within drawers and cabinets. Even when these items were retrieved and placed on the counter, ingredients tended to be again nested within plastic packaging, bottles, or cans. All these nesting objects, from drawers to soup cans, have been designed to be opened (and possibly closed) in particular ways. Our participants exhibit a number of physical manipulations aimed at opening and closing containers that went against, or simply ignored the intent of the design. These practices involved the repurposing of tools to the task of opening containers, and using elbows, knees, or feet to open and close drawers and cupboards while their hands were occupied.

One participant, Anna, explains that for packages she finds hard to open, she uses the handle of a spoon to pry up the ring-pulls, in this case those of crushed tomatoes and baked bean cans needed for her recipe. This demonstrates that physical manipulation skills can also improve with age and familiarity with objects and tools. This can result in somewhat unexpected uses of objects as they are adapted to new purposes. This nevertheless requires a high level of adaptability on the part of the older adult, such as a willingness to try out new things. Figure 3 shows Anna opening a can using one side of the spoon's handle to pry up the ring-pull (3.a), by inserting the spoon handle through the ring-pull (3.b), and then pulling and pushing the spoon in order to remove the lid from the can (3.c).

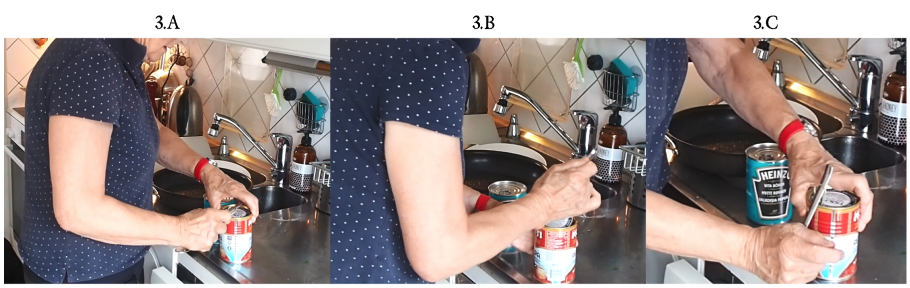

Fig. 3. Anna using a spoon to open a can

Coping strategies were also performed to minimise unnecessary tasks in the kitchen and make the cooking process more efficient. Anna, Maria and Bett mentioned the features (such as rotating in-cupboard shelves or pull-out boards providing extra counter space) and placement of cabinets as important factors affecting the fluency of tasks. In the example shown in Figure 4, Anna, while preparing pancakes, is opening a drawer with her right hand to take flour from the kitchen cabinet, while also holding a bowl and a measuring dish in her left hand. Figure 4 shows Anna pulling the drawer where the flour is placed towards her (4.a), placing the ingredients into the bowl with the measuring cup (4.b), and then pushing the drawer back with her knee to close it (4.c). This is an example of a level of physical performance participants were seen to possess that enabled them to optimise their movements by prioritising task efficiency over simplicity of actions. However, not all participants were physically *capable* of such physical performance. James, for example, struggled to reach items on the lower shelves due to his limited muscle strength and lack of physical mobility.

Fig. 4. Anna using unusual body parts to close the cabinets

4.2 Organisation and Coordination of Tasks

Our different participants organised their cooking following similar series of actions; however, these were not performed in the same linear fashion as in a detailed recipe. In this section, we look at the management of the cooking process itself, and how it comes together through a combination of *switching* between tasks, and *monitoring tasks* as the participants go through the cooking process.

Many moments of cooking involve conducting several tasks simultaneously, which requires a level of organisational fluency to switch between, monitor, and coordinate tasks, and organise tools and objects in the kitchen space. The participants' ability to move from one task to another, to synchronise the cooking process, and to organise tasks and tools in the kitchen in a more or less smooth and effective way appeared to be related to age in terms of mobility and cognitive fluency or capability. While ageing may be accompanied by decreasing mobility, knowledge of familiar recipes and routines may help to compensate for physical limitations.

4.2.1 Switching Between and Synchronising Tasks. In Figure 5, Anna demonstrates fluency in moving quickly from one task to another at the beginning of the meal preparation. She started her cooking session by peeling and chopping potatoes, and continued with fetching the items she needed for the next step from the refrigerator and kitchen cabinets. This fetching step also involved searching for and finding items since many were accessible only at the cost of some reorganisation of the other contents in the cupboard or drawer. Difficulties remembering the specific drawer, shelf, or cupboard also led to searching through alternative storage locations.

In performing these tasks, she quickly moved from chopping to searching, then to peeling, and then once again to searching. Figure 5 shows Anna placing a pan on the stove (5.a), turning to the fridge to fetch a leek (5.b), and then peeling it (5.c). This pattern of switching between tasks was particularly prominent in the early phases of meal preparation when most items in the kitchen space required some organising. This demonstrates

Fig. 5. Anna switching from one task to another

an important component in cooking skill: knowing the recipes, such as the amount and quality of ingredients needed, and the order of actions needed to move forward from one step to the next.

Switching between tasks requires the ability to return to the task that was briefly abandoned for another. Progress in the cooking process includes dealing with the results from the previous tasks which may have changed the spatial layout of the cooking space from when the recipe was started, and the temporal layout in which actions may need to be re-ordered, such as taking into account slower or faster cooking of certain ingredients.

In Figure 6, Emily is frying onions in the pan while also starting to prepare the ground meat to be shaped into meatballs. She fries onions in a pan 6.a) while on the counter, she starts to mix several ingredients in a bowl, (6.b). She then searches for and fetches items from a drawer underneath (6.c). In the meantime, her husband takes over on the stove by stirring the onions in the pan. In this example, switching between tasks is enabled by both the presence of another person attentive to the cooking activity and ready to take over, and by the coordination and temporal alignment of two simultaneous cooking tasks. By reordering, or finishing previous cooking tasks, the onions and meat can be both ready at the right time. This example demonstrates the importance of external intervention for the synchronisation needed to move forward with the task.

4.2.2 Monitoring Tasks. The issue of *when* to switch from one task to another can be simply sequential, with one task started when another is finished. It can also be done according to clock time with the use of timers to prompt the end of one task and the start of another. However, when tasks are to continue simultaneously, the cook must make continuous decisions on when to give priority to one task over another. In order to have the

Fig. 6. Emily switching tasks

Fig. 7. Maria stirring and baking at the same time

information necessary to make these decisions, the participants were visibly *monitoring* the tasks which were not the primary focus of their activities.

The next example (Figure 7) is a case in point. Maria is performing one task (frying minced meat) (7.a), while moving to another (preparing pastry for blind-baking), and seemingly abandoning the original task for a while (7.b). While there are many examples of moving between a number of ongoing tasks, here we want to emphasise the monitoring and task segmentation involved. For the monitoring, the progress of the meat-frying process can be evaluated through multiple senses. Maria is able to look at the pan with her body oriented mid-way between her ongoing task and the stove, she can also hear the frying process, and she can smell the meat, all three senses providing her complementary information to assess how advanced the meat is in its cooking (7.c). Since the aim of this monitoring is to be able to intervene at the pan at the right moment, Maria is also ready to leave behind her current task of preparing the pastry. After retrieving the foil to protect the upper crust but before applying it, in what could be seen as a natural point of transition between tasks, Maria glances towards the pan, but doesn't choose that moment to return to the stove. Only a few moments later, however, Maria stops part way through applying the foil in order to attend to the frying meat. In some cases, this is done more fluently than in others.

In Figure 8, Anna also manages several simultaneous tasks with fluency, namely frying pancakes and watching the potatoes boiling in another pan. She pours batter in the frying pan (8.a), and while waiting for it to cook (8.b.), she lifts the cover off the pan to stir the potatoes (8.c.) and adjust the temperature based on the apparent boiling (8.d). In other words, she makes use of the time waiting for the pancakes to cook to keep an eye on and make small adjustments to the other task. This tight coordination displays awareness of the simultaneous ongoing processes and a sense of timing to know when to turn the pancake, when to stir the potatoes, and when to adjust the temperature. Anna thus optimises her time by turning what would be idle time in one task into active time in another task.

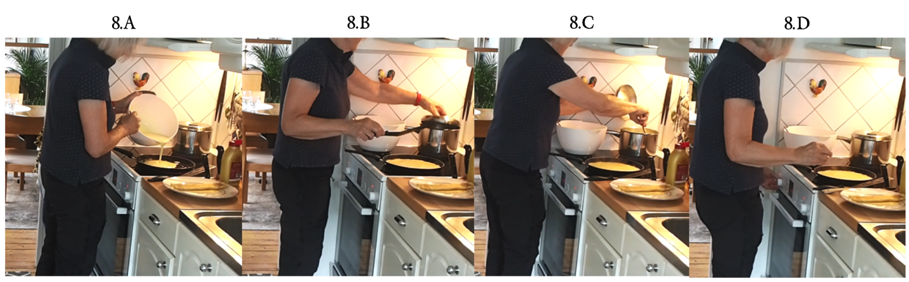

Fig. 8. Anna making pancakes and monitoring the potatoes

4.3 Reorchestration and Reorganisation

As our participants monitored and switched between tasks, they made continual assessments of the spatial, temporal, and sequential state of the kitchen space and their progress towards their goal. Through this process, the participants' courses of actions were influenced by new assessments and transitions in their initial plans. These new assessments of the general situation could be seen to occur in these transitional moments, often leading to new adjustments and the reordering of tasks, which we call reorchestration.

4.3.1 Inserting Tasks. One example of reorganising tasks for spatial alignment can be seen in Figure 9. Martin has recently finished chopping vegetables and is waiting for the water to boil in the pan. Instead of just standing and waiting, he engages in actions which do not seem to be part of the initial plan, or indicated by a recipe.

He reorganises space by moving and tidying tools and objects on the countertop, including placing dirty items in the sink. He then washes his hands (9.a), and begins to move the vegetables towards the pan (9.b). As he reaches the transition point of adding the vegetables to the water in the pan, he makes another aside. He turns back to the sink and completes the task of washing the vegetables (9.c) before placing them in the pan (9.d). Therefore, reorganising space, washing his hands, and washing the vegetables are tasks that are able to be inserted in these transitional moments which elicit reassessment of the general cooking situation.

Fig. 9. Anna making pancakes and monitoring the potatoes

4.3.2 Temporal Coordination in Completing Tasks. Regarding temporal coordination, in a number of situations certain actions are a challenge to complete in the time available with respect to other tasks to attend to. Figure 10 shows Emily rolling meatballs on a chopping board while an initial batch of meatballs is frying in the pan. On hearing them frying, she turns her head several times between the pan and bowl of minced meat (10.a), asks her husband to attend to the frying meatballs, and as he does (10.b), she washes her hands (10.c) and continues to roll the meatballs. Emily seems to be torn between continuing rolling meatballs and attending to the frying ones which risk overcooking. She resolves this tension by asking her husband to turn the frying meatballs, recruiting him to help prevent the food from burning while she continues to roll the ground meat. Her constraints are both temporal, in that the frying has its own temporality and requires timely intervention, and physical: she would need to wash her hands in order to transition from rolling new meatballs to manipulating the handle of the pan and the utensil. Some of these could possibly be seen as "bad planning" by a professional chef, touting the maxims of "mise-in-place" [14], yet many are integral to the act of cooking a meal.

The practice of making a transition also includes the opportunistic insertion of tasks into the flow of the overall cooking process. Some opportunistic tasks revolve around cleaning and organising the kitchen space. Some participants partially cleaned the used cooking implements, or returned spices and ingredients to their respective cupboards and drawers when the opportunity presented itself throughout the cooking process, while others performed all these actions at once or left them entirely until the end of the process before final plating of the

Fig. 10. Emily's husband providing assistance in the kitchen

food. By labelling these tasks as opportunistic, we want to highlight that they were not necessary at that moment to move towards the completion of the cooking session, and yet they were related to the ongoing process.

5 DESIGNING ASSISTANCE

In this section we present a series of design principles for the development of technology to support older adults in the kitchen. To do this, we draw on the empirical findings above, and on the existing literature focusing on the adoption of technology by older adults. Many factors hinder the adoption and acceptance of assistive technologies, including concerns of privacy, trust, stigma and fear of dependence [51].

If the device is designed to compensate for a functional loss, users often perceive the device as having negative consequences on their self-consciousness, such as fear of being stigmatised and not wanting to admit a need [5]. Assistive technology design has considered psychological and socio-emotional design requirements for intelligent assistive devices, such as mobility aids that support navigation in unstructured environments [5]. These include avoiding automatically evoking ageist stereotypes that are associated with assistive devices, providing emotional benefits through social interaction and acceptance, and a sense of ownership and personal significance. While these have generally focused on the usability of telehealth [38] or Ambient Assisted Living applications [37], we draw on the Psychosocial Impact of Assistive Devices Scale [23] as a foundation for the design principles we present in order to respect their skills and abilities. In general, we hope to ensure that the competence, adaptability, and sense of security of older adults will be embedded in the design of assistive technologies for the kitchen.

We present our propositions based not on the technology they rely interaction modality, but rather on the kind of user action for which they provide assistance. In *operational* assistance we focus on designing in order to support the practical operations of manipulating tools necessary to complete actions in the kitchen. In *organisational* assistance we focus on supporting users in many such tasks as they progress towards the goal of completing the act of cooking.

5.1 Operational Assistance

By operational assistance, we mean types of intervention which support the physical manipulation of objects, such as during tasks like stirring, chopping or opening packages. Our suggestions pertain to three types of assistance: Providing physical strength and dexterity, Supporting the maintenance, availability, and selections of tools, and Assessing abilities and difficulties.

In providing direct physical assistance, we see a possible role for a system that stabilises and secures items across the work surface, or without direct physical manipulation by highlighting unstable or insecure items before they are used. A number of issues arising in part from the age-related deterioration in dexterity of our participants could have been ameliorated by freeing the participants from the need to secure bowls, cutting boards, or packets with one hand while manipulating them with the other, thus allowing both hands to be used in manipulation by providing technical support to the object being manipulated.

After reflecting on these proposed system's actions with relation to the Psychosocial Impact of Assistive Devices Scale, it can be seen that the intervention of such systems without careful consideration of the holistic needs of older adult users could be perceived as unwanted or difficult to use, and thus hinder the acceptance and adoption of these devices. As one stated goal is to ensure that people are able to maintain a level of physical and mental activity and a sense of independence and autonomy, forms of support that risk atrophying existing skills, dexterity, or adaptation of the older adult user must be avoided. As such, we propose principles that reinforce existing skills and abilities rather than ones that automate action.

The fluencies and disfluencies observed suggest that ubiquitous systems capable of keeping track of tools and their use could provide welcome support and assistance in the maintenance, availability and selection of tools. In Figure 2, Emily would have benefitted from a system that either helped her find a more suitable knife to chop this onion, or one that ensured that the knife she used had been sharpened before it became necessary for the task in progress.

- Provide support in the maintenance, availability and selection of tools in a way that reinforces user's skills and competences

One important aspect for active and successful ageing is being able to adapt to and cope with age-related changes, which could either mean transitions between life stages, changes in social networks, or changes in physical functioning. Current ageing research tends to address the heterogeneity of these age-related changes among individuals and focus on *resilience* when facing changes: the ability to adapt to adversities [30]. Such cognitive and physical adaptability should be encouraged as a generalisable principle of designing for older adults, and of specific importance in areas critical to continued independence, such as being able to prepare food at home. Focusing on the operational assistance opportunities here, this translates into systems which are themselves able to adapt to explicit or subtle cues that a particular action or use of a tool for a specific task may exceed the abilities of the user at that particular moment in time. This could be because they are carrying out more than one task at a time and have only one hand free, for example, but it could also be in response to tracked earlier attempts at activities with similar dexterity profiles, or explicit statements of changes in ability. This should take into account the variation over time that can occur with respect to one's physical abilities. To support this, drawing on the inventiveness of a range of users could allow such a system to provide suggestions such as using the handle of a spoon to open a can rather than a finger, as in the example above.

- Track and suggest alternative methods to perform tasks in a way that encourages user adaptability

5.2 Organisational Assistance

By organisational assistance, we mean types of intervention which support the organisation and coordination of tasks towards a successful and fulfilling completion of the cooking task. Technically we see that many of the enabling technologies are shared with the operational assistance above. These rely primarily on identifying and tracking the states and locations of tools and ingredients in relation to a model of overall recipe progress allowing the system to track and predict atomised kitchen tasks. In this vein, we propose the following interventions: The suggestion of alternative paths through multiple actions to reach the users' goal; The coordination and temporal alignment of dependent tasks; and the highlighting of opportunities for cleaning, and involving others present.

Our data showed that participants were often engaged in several cooking tasks simultaneously. Moving from one task to another requires fitting in with the temporal alignment of the cooking process. The spatial layout of the kitchen and the location of objects and tools keep changing as the different tasks progress, especially during transitions from one task to the next. Cooking a meal or following a simple series of instructions requires constantly paying attention to several simultaneous processes, each with their own timing, and coordinating them through cognitive and practical, organisational work. Through a particularly effective monitoring and coordination of tasks, cooks are able to optimise their time by turning what would be idle time for one task into effective time for another task.

Organisational assistance could be designed to keep track of the location of the relevant objects and their movements throughout the cooking process, as well as the related tasks and their progression. Supporting users using this model of the cooking process allows for more than just optimising simultaneous progression of the different tasks, or minimising movements in the kitchen space and complex physical performance. Based on this information, the system could suggest what to do next and how to do it, yet this does not have to be presented as instructional and constraining. Such an interface can also be designed to provide users with the means to reflect on the current progression of the tasks, their goals, and to anticipate how different courses of future action will proceed. This will allow them to choose how many of the system's suggestions to use, and how exactly they need to be followed.

- Suggest alternative actions and coordinate tasks in a way that it encourages user participation

Our empirical study also shows that planning and organising cooking tasks are not static or pre-set, but are continually adjusted in the ongoing course of action. Transitions between different steps of cooking present opportunities for reassessing the general process, and often lead to revising initial plans and inserting unplanned actions. As such, systems should support the reorchestration and reorganisation of tasks and objects. Here, we propose two additional types of assistance: *Planning* the temporal and physical alignment of tasks, and *Assessing* the need for external assistance. Our study showed that transitions between different cooking steps presented opportunities for reassessing the general process, and often led to revising initial plans and inserting unplanned actions. As tensions emerge between continuing the ongoing task and attending to another requiring action, cooks could also recruit another person present to temporally assist with tasks needing concurrent attention. These moments when reassessment is required, along with the time-pressure from the ongoing cooking tasks, can create stress for the home cook. There are opportunities for a system to pre-empt the need to make decisions under time pressure, support the making of such choices quickly and with greater certainty to their outcome, or overall to provide the security of a safety net which will help the user recover the meal from most minor mishaps in the process.

- Assess and reassess the progression of tasks in a way that reinforces the user's sense of security

In general, organisational assistance highlights an important feature of cooking which needs to be considered in the design of kitchen technology: systems should be neither too prescriptive (suggesting, not enforcing) nor too invasive (no intervention in certain domains or moments), thus providing, for example, the means to set different degrees of intervention and to silence the system easily and contextually.

6 DISCUSSION

In this study, we have uncovered physical, organisational and coordinational tasks performed in the kitchen space for the purpose of providing a basis for the future development of technology to enhance older adults' well-being and allow them to stay in their own homes longer. Our study has complemented research on human-food interaction and assistive technology for older adults by a) investigating the organisational and coordinational aspects involved in the cooking process, b) showing the physical, spatial, and temporal alignment of different cooking tasks, and c) outlining principles for design interventions that could be implemented and tested in assistive technology design for older adults. In this discussion, we explore the challenges we discovered, and the directions for future research they point to for the development of fitting technological interventions.

6.1 Designing Conversational User Interfaces in the Kitchen

One interaction that lends itself to the type of supporting, suggesting, and reminding actions outlined above is the conversational user interface. This could provide the input and output for a system able to anticipate and support swapping between tasks by suggesting where to find needed items, and reminding the user of needed recipe ingredients and ordering. Precursors of such systems are under development. For instance, Hashimoto et al., [19] have developed a sensor-embedded user-centric smart kitchen system where the user can cook normally, and the system can understand the users' actions in the kitchen, thus providing instructions and allowing flexibility in following the recipes. Ubiquitous computing technologies that augment objects and the environment with sensing capabilities can enable the user learning process by providing situated and task-related feedback, instructions, and reminders in the kitchen [20]. For users with cognitive impairments, the design of communal kitchens in sheltered housing can provide support in learning and performing cooking tasks independently, in collaboration with their caregivers and community [28].

6.2 Perception and Representation of Cooking Tasks

Persons cooking a meal at home do not necessarily follow a predefined plan for the whole process from choosing a recipe to plating a meal. This means that building systems based upon a sequential process model for understanding a recipe is destined to fail to meet the needs and goals of the user. The design of systems to fit with and support the practices of cooking at home as examined above needs a more complex model of the activity.

This also means that in order to seamlessly support the overall task of cooking a meal, a system needs a representation that take into account both the sequential relationships between some tasks (e.g., the onions cannot be fried until they are chopped) and the temporal relationships between others (e.g., if the frying of the onions is started before the meat is defrosted, this will likely result in burnt onions). Conversely, it must also be able to represent the sequential and temporal *disconnects* between tasks to give opportunities to insert, slow down, or speed up tasks for the reasons outlined above.

This follows through to the perception requirements for such systems. Not only must tasks be identified as users perform them, but their ongoing progress must be monitored and projected in order to support real, live relationships between the different tasks carried out. While technologically it may be tempting to leapfrog visual and audible cues from appliances, tools, and the cooking ingredients themselves in favour of direct sensing of, for example, temperature, we see this as a potential issue for perception—not of the system, but of the user. These systems need be collaborative and supportive of human cooking, rather than automating it, and then need to build upon the same explainable and understandable cues that the users would reason about when using the complex systems envisaged. Preserving the user's ability to understand why the system is suggesting or taking action in turn preserves their ability to trust, disagree, or subvert the system to their own ends.

6.3 Physical and Spatial Collaboration Between Human and System

The modern kitchen is a prime site for the development and testing of assistant services in the form of collaborative manufacturing, where the human and robotic elements of an overall system work in tandem to produce the desired products – in this case a healthy, tasty, and timely meal. Our video analysis has shown that the participants would benefit from assistance in chopping, opening, carrying, and stirring. What is more pressing is to provide operational and instructional assistance that can be "ready at hand" without the need to invest time, energy and forethought in choosing and finding the right tool at the right moment. The types of systems needed to support physical tasks should help improve the fluency of the whole cooking process.

Without the complex physical interactions that may be necessary for such a system, the spatial organisation of the kitchen space could be supported through hints, reminders, and suggestions which would rely on the human as the actuator in the space. These could result in arranging and locating the tools required, or pre-emptively suggesting the retrieval of a long-forgotten kitchen gadget with motivating connections made between the tool and a number of upcoming tasks it could help with. These interventions could also provide assistance in ensuring that the arrangement of objects in the kitchen did not significantly hinder upcoming, time sensitive tasks such as having space on a heat-resistant pad to place a hot dish from the oven on before retrieving it.

6.4 Designing Digital Kitchens for Ageing in Place

Our study has examined the age-specificity of cooking a meal at home by analysing the complexities of these tasks among older adults aged 65 and over, and by paying attention to physical and cognitive skills that could possibly influence the performances of these tasks in the kitchen. Attention to physical and cognitive tasks allowed us to differentiate between possible types of interventions depending on whether they provided operational and/or organisational support. This, in turn, makes it possible to enhance skills and abilities for independent living and maintaining physical and mental functioning in a specific domestic task [49]. As we saw from the data, older adults can adapt to adversities, whether they are limited by their own skills and capabilities, or by the poor quality of the tools and ingredients they are using. Therefore, intelligent assistive devices focusing on operational assistance in physical kitchen tasks also need to provide organisational assistance to ensure user participation.

One of the most important benefits that assistive technologies in the kitchen can provide is a sense of safety and security [3, 13]. Although older adults can easily find coping strategies to compensate for age-related changes in physical functioning, by switching tools or limiting the amount of ingredients in hand, cognitive and organisational tasks such as monitoring or synchronising separate tasks to achieve a coherent cooking outcome will be much more difficult to achieve without external help. Design interventions for monitoring, for instance, can provide a sense of safety in terms of freeing up time and effort from monitoring, without needing much input from the older adult. This, in turn, could result in a successful outcome in the kitchen with less effort placed in time-sensitive tasks, and perhaps encourage older adults to try out more complicated recipes that need more temporal coordination.

The design interventions proposed in this study were based on a combination of operational and organisational assistance, and changes in a user's actions. As such, assistive technologies in the kitchen enhance user competence and participation, rather than automate physical tasks. HCI research has recently addressed new approaches to designing assistive technologies for older adults in a way that maintains their existing abilities [30, 37]. Our study has outlined design proposals for enhancing a user's competence, adaptability, and sense of security in operational and organisational assistance in kitchen tasks. Future research should focus on operationalising these design proposals in empirical research on kitchen technologies for older adults, and investigating these within the framework of successful and active ageing; in other words, allowing the ageing population to remain active, engaged, and healthy for a longer period of time.

7 CONCLUSION

Our study has advanced research on human-food interaction and assistive technology design by taking a close look at the cooking actions older adults perform at home. Our study has focused on investigations of the planning and orchestration of cooking a meal in moments of change, where one task is left behind and another is attended to, as well as the monitoring necessary to initiate these task changes at the correct time. In looking closely at the physical manipulations performed by older adults, we have concentrated on the common activities of cutting and chopping, opening packaging and containers, and moving and organising the various objects in and around the cooking area. We envision future research on assistive technologies in the kitchen to focus on the development of cross-platform perception and actuation systems for physical tasks, followed by testing and evaluation of the impacts these technologies have on older adults' health and well-being, based on the design proposals developed in this study.

ACKNOWLEDGMENTS

This study was supported by KTH Digital Futures 'Advanced Adaptive Intelligent Systems' project. We would also like to thank all participants in video recordings for their valuable contribution to the study.

REFERENCES

[1] Ferran Altarriba Bertran, Samvid Jhaveri, Rosa Lutz, Katherine Isbister, and Danielle Wilde. 2019. Making Sense of Human-Food Interaction. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow Scotland Uk, 1–13. https://doi.org/10.1145/3290605.3300908

[2] Hideki Aoyama, Motoyuki Ozeki, and Yuichi Nakamura. 2009. Smart cooking support system based on interaction reproducing model. In *Proceedings of the ACM multimedia 2009 workshop on Multimedia for cooking and eating activities - CEA '09*. ACM Press, Beijing, China, 39. https://doi.org/10.1145/1630995.1631003

[3] Rubén Blasco, Álvaro Marco, Roberto Casas, Diego Cirujano, and Richard Picking. 2014. A Smart Kitchen for Ambient Assisted Living. *Sensors* 14, 1 (Jan. 2014), 1629–1653. https://doi.org/10.3390/s140101629

[4] Margot Brereton, Alessandro Soro, Kate Vaisutis, and Paul Roe. 2015. The Messaging Kettle: Prototyping Connection over a Distance between Adult Children and Older Parents. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, Seoul Republic of Korea, 713–716. https://doi.org/10.1145/2702123.2702462

[5] Aimée K. Bright and Lynne Coventry. 2013. Assistive technology for older adults: psychological and socio-emotional design requirements. In *Proceedings of the 6th International Conference on PErvasive Technologies Related to Assistive Environments - PETRA '13*. ACM Press, Rhodes, Greece, 1–4. https://doi.org/10.1145/2504335.2504344

[6] Barry Brown, Alex S. Taylor, Shahram Izadi, Abigail Sellen, Joseph Jofish' Kaye, and Rachel Eardley. 2007. Locating Family Values: A Field Trial of the Whereabouts Clock: (Nominated for the Best Paper Award). In *UbiComp 2007: Ubiquitous Computing*, David Hutchison, Takeo Kanade, Josef Kittler, Jon M. Kleinberg, Friedemann Mattern, John C. Mitchell, Moni Naor, Oscar Nierstrasz, C. Pandu Rangan, Bernhard Steffen, Madhu Sudan, Demetri Terzopoulos, Doug Tygar, Moshe Y. Vardi, Gerhard Weikum, John Krumm, Gregory D. Abowd, Aruna Seneviratne, and Thomas Strang (Eds.). Vol. 4717. Springer Berlin Heidelberg, Berlin, Heidelberg, 354–371. https://doi.org/10.1007/978-3-540-74853-3_21 Series Title: Lecture Notes in Computer Science.

[7] Min Zhen Chai, Alessandro Soro, Paul Roe, and Margot Brereton. 2017. Cooking Together at a Distance: Sustain Connectedness for Long Distance Families. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. ACM, Denver Colorado USA, 2437–2444. https://doi.org/10.1145/3027063.3053183

[8] Rob Comber, Jettie Hoonhout, Aart van Halteren, Paula Moynihan, and Patrick Olivier. 2013. Food practices as situated action: exploring and designing for everyday food practices with households. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Paris France, 2457–2466. https://doi.org/10.1145/2470654.2481340

[9] Hilary Davis, Bjorn Nansen, Frank Vetere, Toni Robertson, Margot Brereton, Jeannette Durick, and Kate Vaisutis. 2014. Homemade cookbooks: a recipe for sharing. In *Proceedings of the 2014 conference on Designing interactive systems*. ACM, Vancouver BC Canada, 73–82. https://doi.org/10.1145/2598510.2598590

[10] Antonella De Angeli, Mlađan Jovanović, Andrew McNeill, and Lynne Coventry. 2020. Desires for active ageing technology. *International Journal of Human-Computer Studies* 138 (June 2020), 102412. https://doi.org/10.1016/j.ijhcs.2020.102412

[11] Markéta Dolejšová, Danielle Wilde, Ferran Altarriba Bertran, and Hilary Davis. 2020. Disrupting (More-than-) Human-Food Interaction: Experimental Design, Tangibles and Food-Tech Futures. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. ACM, Eindhoven Netherlands, 993–1004. https://doi.org/10.1145/3357236.3395437

[12] Keisuke Doman, Cheng Ying Kuai, Tomokazu Takahashi, Ichiro Ide, and Hiroshi Murase. 2012. Smart VideoCooKing: a multimedia cooking recipe browsing application on portable devices. In *Proceedings of the 20th ACM international conference on Multimedia - MM '12*. ACM Press, Nara, Japan, 1267. https://doi.org/10.1145/2393347.2396435

[13] Maurizio Ficocelli and Goldie Nejat. 2012. The Design of an Interactive Assistive Kitchen System. *Assistive Technology* 24, 4 (Dec. 2012), 246–258. https://doi.org/10.1080/10400435.2012.659834

[14] Hennie Fisher and Ina Louw. 2020. Teaching mise-en-place: Student perceptions of the cooking pro forma process. *International Journal of Gastronomy and Food Science* 22 (Dec. 2020), 100245. https://doi.org/10.1016/j.ijgfs.2020.100245

[15] Jodi Forlizzi, Carl Disalvo, and Francine Gemperle. 2004. Assistive Robotics and an Ecology of Elders Living Independently in Their Homes. *Human-Computer Interaction* 19 (06 2004), 25–59. https://doi.org/10.1207/s15327051hci1901&2_3 Artwork Size: 5230220 Bytes Publisher: Carnegie Mellon University.

[16] Catherine Grevet, Anthony Tang, and Elizabeth Mynatt. 2012. Eating alone, together: new forms of commensality. In *Proceedings of the 17th ACM international conference on Supporting group work - GROUP '12*. ACM Press, Sanibel Island, Florida, USA, 103. https://doi.org/10.1145/2389176.2389192

[17] Andrea Grimes and Richard Harper. 2008. Celebratory technology: new directions for food research in HCI. In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*. ACM Press, Florence, Italy, 467. https://doi.org/10.1145/1357054.1357130

[18] Reiko Hamada, Jun Okabe, Ichiro Ide, Shin'ichi Satoh, Shuichi Sakai, and Hidehiko Tanaka. 2005. Cooking navi: assistant for daily cooking in kitchen. In *Proceedings of the 13th annual ACM international conference on Multimedia - MULTIMEDIA '05*. ACM Press, Hilton, Singapore, 371. https://doi.org/10.1145/1101149.1101228

[19] Atsushi Hashimoto, Tetsuro Sasada, Yoko Yamakata, Shinsuke Mori, and Michihiko Minoh. 2014. KUSK dataset: toward a direct understanding of recipe text and human cooking activity. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication*. ACM, Seattle Washington, 583–588. https://doi.org/10.1145/2638728.2641338

[20] Clare J. Hooper, Patrick Olivier, Anne Preston, Madeline Balaam, Paul Seedhouse, Daniel Jackson, Cuong Pham, Cassim Ladha, Karim Ladha, and Thomas Plötz. 2012. The french kitchen: task-based learning in an instrumented kitchen. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing - UbiComp '12*. ACM Press, Pittsburgh, Pennsylvania, 193. https://doi.org/10.1145/2370216.2370246

[21] David O. Johnson, Raymond H. Cuijpers, James F. Juola, Elena Torta, Mikhail Simonov, Antonella Frisiello, Marco Bazzani, Wenjie Yan, Cornelius Weber, Stefan Wermter, Nils Meins, Johannes Oberzaucher, Paul Panek, Georg Edelmayer, Peter Mayer, and Christian Beck. 2014. Socially Assistive Robots: A Comprehensive Approach to Extending Independent Living. *International Journal of Social Robotics* 6, 2 (April 2014), 195–211. https://doi.org/10.1007/s12369-013-0217-8

[22] Merel M. Jung and Geke D. S. Ludden. 2019. What Do Older Adults and Clinicians Think About Traditional Mobility Aids and Exoskeleton Technology? *ACM Transactions on Human-Robot Interaction* 8, 2 (June 2019), 1–17. https://doi.org/10.1145/3311789

[23] Jeffrey Jutai and Hy Day. 2002. Psychosocial Impact of Assistive Devices Scale (PIADS). *Technology and Disability* 14, 3 (Sept. 2002), 107–111. https://doi.org/10.3233/TAD-2002-14305

[24] Rajiv Khosla, Khanh Nguyen, and Mei-Tai Chu. 2017. Human Robot Engagement and Acceptability in Residential Aged Care. *International Journal of Human–Computer Interaction* 33, 6 (June 2017), 510–522. https://doi.org/10.1080/10447318.2016.1275435

[25] Rohit Ashok Khot, Florian Mueller, and Damon Young. 2019. Human-Food Interaction. *Foundations and Trends® in Human–Computer Interaction* 12, 4 (2019), 238–415. https://doi.org/10.1561/1100000074

[26] Yui Kita and Jun Rekimoto. 2013. Thermal visualization on cooking. In *2013 23rd International Conference on Artificial Reality and Telexistence (ICAT)*. IEEE, Tokyo, 92–96. https://doi.org/10.1109/ICAT.2013.6728912

[27] Hubert Knoblauch and Bernt Schnettler. 2012. Videography: analysing video data as a 'focused' ethnographic and hermeneutical exercise. *Qualitative Research* 12, 3 (June 2012), 334–356. https://doi.org/10.1177/1468794111436147

[28] Thomas Kosch, Paweł W. Woźniak, Erin Brady, and Albrecht Schmidt. 2018. Smart Kitchens for People with Cognitive Impairments: A Qualitative Study of Design Requirements. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–12. https://doi.org/10.1145/3173574.3173845

[29] Amanda Lazar, Hilaire J. Thompson, Anne Marie Piper, and George Demiris. 2016. Rethinking the Design of Robotic Pets for Older Adults. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*. ACM, Brisbane QLD Australia, 1034–1046. https://doi.org/10.1145/2901790.2901811

[30] Hee Rin Lee and Laurel D. Riek. 2018. Reframing Assistive Robots to Promote Successful Aging. *ACM Transactions on Human-Robot Interaction* 7, 1 (May 2018), 1–23. https://doi.org/10.1145/3203303

[31] Valerie Leuty, Jennifer Boger, Laurel Young, Jesse Hoey, and Alex Mihailidis. 2013. Engaging Older Adults with Dementia in Creative Occupations Using Artificially Intelligent Assistive Technology. *Assistive Technology* 25, 2 (April 2013), 72–79. https://doi.org/10.1080/10400435.2012.715113

[32] Josephine McMurray, Gillian Strudwick, Cheryl Forchuk, Adam Morse, Jessica Lachance, Arani Baskaran, Lauren Allison, and Richard Booth. 2017. The Importance of Trust in the Adoption and Use of Intelligent Assistive Technology by Older Adults to Support Aging in Place: Scoping Review Protocol. *JMIR Research Protocols* 6, 11 (Nov. 2017), e218. https://doi.org/10.2196/resprot.8772

[33] W. Ben Mortenson, Louise Demers, Marcus J. Fuhrer, Jeffrey W. Jutai, James Lenker, and Frank DeRuyter. 2013. Effects of an Assistive Technology Intervention on Older Adults with Disabilities and Their Informal Caregivers: An Exploratory Randomized Controlled Trial. *American Journal of Physical Medicine & Rehabilitation* 92, 4 (April 2013), 297–306. https://doi.org/10.1097/PHM.0b013e31827d65bf

[34] Bjorn Nansen, Hilary Davis, Frank Vetere, Mikael Skov, Jeni Paay, and Jesper Kjeldskov. 2014. Kitchen kinesics: situating gestural interaction within the social contexts of family cooking. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: the Future of Design*. ACM, Sydney New South Wales Australia, 149–158. https://doi.org/10.1145/2686612.2686635

[35] Jeni Paay, Jesper Kjeldskov, and Mikael B. Skov. 2015. Connecting in the Kitchen: An Empirical Study of Physical Interactions while Cooking Together at Home. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*. ACM, Vancouver BC Canada, 276–287. https://doi.org/10.1145/2675133.2675194

[36] Jeni Paay, Jesper Kjeldskov, Mikael B. Skov, and Kenton O'Hara. 2012. Cooking together: a digital ethnography. In *Proceedings of the 2012 ACM annual conference extended abstracts on Human Factors in Computing Systems Extended Abstracts - CHI EA '12*. ACM Press, Austin, Texas, USA, 1883. https://doi.org/10.1145/2212776.2223723

[37] Irina Paraschivoiu, Anna Winkler, and Alexander Meschtscherjakov. 2020. Beyond "Assistive": Four Tensions in the Design of AAL Based on the Capability Approach. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference*. ACM, Eindhoven Netherlands, 67–72. https://doi.org/10.1145/3393914.3395859

[38] Bambang Parmanto, Allen Nelson Lewis, Jr., Kristin M. Graham, and Marnie H. Bertolet. 2016. Development of the Telehealth Usability Questionnaire (TUQ). *International Journal of Telerehabilitation* 8, 1 (July 2016), 3–10. https://doi.org/10.5195/ijt.2016.6196

[39] John W. Rowe and Robert L. Kahn. 2015. Successful Aging 2.0: Conceptual Expansions for the 21st Century. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences* 70, 4 (July 2015), 593–596. https://doi.org/10.1093/geronb/gbv025

[40] Ayaka Sato, Keita Watanabe, and Jun Rekimoto. 2013. MimiCook: a cooking assistant system with situated guidance. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction - TEI '14*. ACM Press, Munich, Germany, 121–124. https://doi.org/10.1145/2540930.2540952

[41] Ayaka Sato, Keita Watanabe, and Jun Rekimoto. 2014. Shadow Cooking: Situated Guidance for a Fluid Cooking Experience. In *Universal Access in Human-Computer Interaction. Aging and Assistive Environments*, David Hutchison, Takeo Kanade, Josef Kittler, Jon M. Kleinberg, Alfred Kobsa, Friedemann Mattern, John C. Mitchell, Moni Naor, Oscar Nierstrasz, C. Pandu Rangan, Bernhard Steffen, Demetri Terzopoulos, Doug Tygar, Gerhard Weikum, Constantine Stephanidis, and Margherita Antona (Eds.). Vol. 8515. Springer International Publishing, Cham, 558–566. https://doi.org/10.1007/978-3-319-07446-7_54 Series Title: Lecture Notes in Computer Science.

[42] Jürgen Scheible, Arnd Engeln, Michael Burmester, Gottfried Zimmermann, Tobias Keber, Uwe Schulz, Sabine Palm, Markus Funk, and Uwe Schaumann. 2016. SMARTKITCHEN Media Enhanced Cooking Environment. In *Proceedings of the 6th International Conference on the Internet of Things*. ACM, Stuttgart Germany, 169–170. https://doi.org/10.1145/2991561.2998471

[43] M. Schneider. 2007. The semantic cookbook: sharing cooking experiences in the smart kitchen. In *3rd IET International Conference on Intelligent Environments (IE 07)*, Vol. 2007. IEE, Ulm, Germany, 416–423. https://doi.org/10.1049/cp:20070401

[44] Frances Short. 2006. *Kitchen secrets: the meaning of cooking in everyday life*. Berg, Oxford ; New York. OCLC: ocm62593466.

[45] Lucia Terrenghi. 2009. Computing Technologies in the Kitchen: The Living Cookbook as a Design for Mindful Cooking Experiences. *Material Culture Review* 70 (Jun. 2009), 9 pages. https://journals.lib.unb.ca/index.php/MCR/article/view/18164

[46] Lucia Terrenghi, Otmar Hilliges, and Andreas Butz. 2007. Kitchen stories: sharing recipes with the Living Cookbook. *Personal and Ubiquitous Computing* 11, 5 (May 2007), 409–414. https://doi.org/10.1007/s00779-006-0079-2

[47] Daisuke Uriu, Mizuki Namai, Satoru Tokuhisa, Ryo Kashiwagi, Masahiko Inami, and Naohito Okude. 2012. panavi: recipe medium with a sensors-embedded pan for domestic users to master professional culinary arts. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*. ACM Press, Austin, Texas, USA, 129. https://doi.org/10.1145/2207676.2207695

[48] J. van Hoof, H.S.M. Kort, P.G.S. Rutten, and M.S.H. Duijnstee. 2011. Ageing-in-place with the use of ambient intelligence technology: Perspectives of older users. *International Journal of Medical Informatics* 80, 5 (May 2011), 310–331. https://doi.org/10.1016/j.ijmedinf.2011.02.010

[49] J. L. Wiles, A. Leibing, N. Guberman, J. Reeve, and R. E. S. Allen. 2012. The Meaning of "Aging in Place" to Older People. *The Gerontologist* 52, 3 (June 2012), 357–366. https://doi.org/10.1093/geront/gnr098

[50] Lei Xie, Yafeng Yin, Xiang Lu, Bo Sheng, and Sanglu Lu. 2013. iFridge: an intelligent fridge for food management based on RFID technology. In *Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication*. ACM, Zurich Switzerland, 291–294. https://doi.org/10.1145/2494091.2494181

[51] Salifu Yusif, Jeffrey Soar, and Abdul Hafeez-Baig. 2016. Older people, assistive technologies, and the barriers to adoption: A systematic review. *International Journal of Medical Informatics* 94 (Oct. 2016), 112–116. https://doi.org/10.1016/j.ijmedinf.2016.07.004