The Digital Cooking Coach: Using Visual and Auditory In-Situ Instructions to Assist Cognitively Impaired during Cooking

Thomas Kosch
LMU Munich
Munich, Germany
thomas.kosch@ifi.lmu.de

Kevin Wennrich
University of Stuttgart
Stuttgart, Germany
st111170@stud.uni-stuttgart.de

Daniel Topp
University of Stuttgart
Stuttgart, Germany
st102550@stud.uni-stuttgart.de

Marcel Muntzinger
University of Stuttgart
Stuttgart, Germany
inf87352@stud.uni-stuttgart.de

Albrecht Schmidt
LMU Munich
Munich, Germany
albrecht.schmidt@ifi.lmu.de

ABSTRACT

To date, approximately 20% of the world population lives with a level of cognitive impairment. In Western Europe, sheltered living facilities have emerged which collaboratively convey and train daily living skills for people with cognitive disabilities. This includes cooking as an important communal activity. However, tenants receive rudimentary cooking training since most facilities are affected by a worker shortage as they are driven on a voluntary basis. In this work, we investigate how digital *in-situ assistance* can be used to convey cooking instructions in kitchens. We conduct a user study (N=10) over two weeks in a sheltered living facility to evaluate the cooking performance and subjective perception between *in-situ assistance* and *caretaker assistance*. We find that *caretaker assistance* requires less time to prepare a meal when participants cooked previously with *in-situ assistance*. Our results are complemented by positive feedback of using *in-situ instructions*. We discuss how *in-situ assistance* enables independent cooking sessions in living environments for cognitively impaired.

CCS CONCEPTS

• **Human-centered computing → Accessibility design and evaluation methods**; *Accessibility technologies*; Accessibility systems and tools.

KEYWORDS

Accessibility; Cognitive Impairment; Smart Kitchens

ACM Reference Format:
Thomas Kosch, Kevin Wennrich, Daniel Topp, Marcel Muntzinger, and Albrecht Schmidt. 2019. The Digital Cooking Coach: Using Visual and Auditory In-Situ Instructions to Assist Cognitively Impaired during Cooking. In *The 12th PErvasive Technologies Related to Assistive Environments Conference (PETRA '19), June 5–7, 2019, Rhodes, Greece.* ACM, New York, NY, USA, Article 4, 8 pages. https://doi.org/10.1145/3316782.3321524

PETRA '19, June 5–7, 2019, Rhodes, Greece

ACM ISBN 978-1-4503-6232-0/19/06…$15.00
https://doi.org/10.1145/3316782.3321524

Figure 1: Assistive system providing visual and auditory *in-situ assistance* that supports people with cognitive deficiencies during cooking tasks.

1 INTRODUCTION

Today, approximately 20% of the world population is affected by some sort of cognitive deficiency [29]. Cognitively impaired may have difficulties in learning, remembering information, and decision making as the result of genetic conditions, injuries, or age-related effects [30]. The number of individuals with cognitive impairments is expected to rise since the average lifespan increases continuously. The "United Nations Convention on the Rights of Persons with Disabilities" [26] states that the fundamental human rights of people with cognitive disabilities need to be preserved. This includes their right on independent living.

To preserve the rights of a person with disabilities, volunteer and government-driven sheltered living facilities have emerged to foster and train independent living skills. Sheltered living facilities are housing communities where tenants with cognitive impairments live together under the supervision of at least one caretaker. These facilities supervise between 20 to 30 tenants and provide methodical instructions on how to accomplish daily life tasks taught by expert staff. The final goal is to enable independent living by teaching fundamental living skills on how to collaboratively work together with other people affected by cognitive impairments. Thereby, the organization supports tenants to move into a shared flat where four to six people help each other without any caretaker supervision.

Communal cooking is such an activity that combines the need for specialized skills and collaboration with other people. Tenants learn how they contribute to the community by accomplishing their kitchen duties. It is common that instructions between caretaker and tenants are communicated verbally [22]. However, this *caretaker assistance* rarely adjusts to the individual level of cognitive impairment since specialized staff is needed that works with certain types of cognitive impairment. Complemented by a worker shortage in the field, this misses its potential for people who have recently moved into a sheltered living facility which require intensive supervision. Furthermore, the individual life skills are not fostered directly as feedback is provided on a general basis rather on a personalized one. Context-aware assistance by displays [14] or *in-situ assistance* [12] have shown to be effective in supporting people with cognitive impairments at workplaces. The assembly performance and motivation of workers increased while the caused workload for supervisor and instructors remained low. Thus, the integration of *in-situ assistance* in kitchen environments could provide a similar increase in performance and motivation. Furthermore, digital *in-situ assistance* can be deployed at sheltered living facilities or communal apartments to enable independent cooking for cognitively impaired.

This paper presents a study which compares the cooking performance and user experience between regular *caretaker assistance* and *in-situ assistance* (see Figure 1). Our apparatus facilitates visual and auditory instructions to convey cooking instructions. We conduct a study over two weeks with ten participants in a sheltered living facility that were supported by either *caretaker assistance* or *in-situ assistance*. Our findings reveal that cooking times increase when initially using *in-situ assistance*. After cooking with *in-situ assistance* for the first time, cooking times decrease fundamentally when cooking with *caretaker assistance*. However, this effect could not be observed when starting with *caretaker assistance*.

The contribution of our paper is threefold: We (1) report on a user study that investigates the cooking performances between *caretaker assistance* and *in-situ assistance*. Furthermore, we (2) present subjective feedback about the individual cooking experience with each feedback modality. Finally, we (3) discuss how a combination of *caretaker assistance* and *in-situ assistance* enables independent cooking for cognitively impaired people.

2 RELATED WORK

The impact of integrating assistive technologies in home environments has been investigated by various researchers before. In the following, we summarize relevant research related to our work.

2.1 Supporting Cognitively Impaired

Assistive technologies that focus on support for elderly and cognitively impaired was the subject of previous research. Assistive systems require design implications and guidelines to coalesce kitchen environments with home environments. For this purpose, Pollack et al. [31] explored how assistive technologies in home environments can be designed to support impaired people. This includes a taxonomy for assistive computing systems. Bouchard et al. [4] developed and evaluated a plan recognition framework for smart homes using microsensors. These sensor made contextual data available [23] of which people with dementia and caretaker personnel benefited from activity recognition provided by the framework. Furthermore, Arcelus et al. [1] used a variety of sensors, such as microphone arrays and accelerometers, to collect contextual information. The collected data was used to train an artificial intelligence that provided individual context-aware assistance. Mihailidis et al. [25] found that the integration of training activities into daily life tasks reduced the development of dementia. Serious games that simulate regular daily kitchen tasks have shown positive effects on people with cognitive impairments [24]. Through qualitative inquiries in a sheltered living facility, Kosch et al. [22] found design implications in smart kitchens for people with cognitive impairments. Ethical aspects need to be considered before using assistive technologies in real-world environments since, depending on the level of impairment, individuals are limited in their ability to give consent [34]. However, the integration of assistive technologies raises ethical considerations regarding individual autonomy in home environments. This includes privacy concerns [9, 10] and user acceptance [5, 11].

Providing *in-situ assistance* at industrial workplaces through spatial augmented reality has shown mental alleviation for people with cognitive impairments [6, 12]. Projecting visual in-situ information enhanced the overall assembly efficiency regarding the number of errors and task completion time [14]. Furthermore, less cognitive resources were utilized [15]. Motivation can be increased or maintained by incorporating gamification into the working environment of cognitively impaired [18, 19]. Kosch et al. [20, 21] researched how important notifications, such as alert messages and errors, can be conveyed for people with cognitive deficiencies. They found that visual and auditory notifications outperform tactile error alerts with respect to usability and understanding.

2.2 Assistive Technologies in Smart Kitchens

Integrating assistive technologies in kitchen environments has been the focus of various researcher before. Scheible et al. [32] presented how smart kitchens can be designed to enhance the overall cooking experience. With the availability of microsensors, a huge number of contextual data in kitchen environments can be collected. Thereby, Hashimoto et al. [16] analyzed behavioral data to recognize the current cooking action and prepared food materials. Blasco et al. [2] developed and evaluated a smart kitchen system for older adults within real-world scenarios. They found that their participants benefited from cognitive assistance during the cooking sessions. Besides of providing support during meal preparation, smart kitchens can provide contextual nutrition-aware information. Based on this, suited recipes can be mediated to ensure the intake of important nutritions [7, 8]. Cooking has become a social activity in which recipes are shared and prepared together. Therefore, Schneider et al. [33] present the "Semantic Cookbook" which is able to capture, share, and exploit cooking experiences semantically. This way recipes can be recorded shared among other smart kitchens and relatives. Since most recipes are passed down to the next generations, Terrenghi et al. [35] developed the "Living Cookbook". Cooking experiences were recorded to practice meal preparation techniques and to teach people who are unfamiliar with cooking. Previous research has incorporated language learning tasks into smart kitchens [17]. Design recommendations were presented for integrating task-based learning within the meal preparation process. Miyawaki et al. [27] developed cooking support for people with higher brain dysfunction. The use of their system during rehabilitation training has shown positive effects. Prototyping new smart kitchen solutions requires a robust testing environment. Olivier et al. [28] presented a prototype setting in which new smart kitchen solutions can be evaluated. Several augmented reality-based applications in smart kitchen environments were evaluated by Bonanni et al. [3]. This included the assessment of usability, attention, cognitive workload.

Previous work has invested effort into the construction, evaluation, and integration of assistive technologies in home environments. However, the influence of in-situ cooking assistance for cognitively impaired has not been considered yet. To close this gap, we conducted a field study in a sheltered living facility where people with cognitive impairments cooked either with (a) traditional *caretaker assistance* or (b) *in-situ assistance*. We report on differences in cooking performance and subjective feedback between both cooking modalities.

3 USER STUDY

Related research has informed how accessibility can be ubiquitously integrated into daily life situations to compensate cognitive impairments. At the same time, assistive technologies have proliferated into home environments which are available for the wider public. However, how assistive technologies impact the behavior of cognitively impaired in sheltered living facilities during cooking has not been explored yet. In the following, we present a study that compares *in-situ assistance* and *caretaker assistance* in terms of cooking performance as well as subjectively perceived feedback. We state our research questions as follows:

RQ 1: How does *in-situ assistance* changes the cooking performance, measured by the overall meal preparation time, compared to *caretaker assistance*?

RQ 2: How is *in-situ assistance* subjectively perceived compared to *caretaker assistance*?

3.1 Evaluation

We extended the system of Funk et al. [13, 14] by functional modules to provide additional visual and auditory feedback. The main system that tracks cooking steps and provides feedback to the cooking area consists of multiple aluminum profiles assembled together. The profiles enable to mount different hardware on top of the cooking area by placing the construction on the cooking area. The system uses a top-mounted Kinect v2[1] which is mounted 1.35 meters above the cooking area to detect finished cooking steps. A projector which is mounted 1.50 meters above the working area presents visual cooking instructions [12]. Dedicated audio speakers, placed next to the cooking area, provided auditory feedback by playing verbally recorded cooking instructions (see Figure 2). In the following, we describe the cooking feedback modalities which were facilitated in the study.

[1]https://developer.microsoft.com/en-us/windows/kinect - last access 2019-01-23

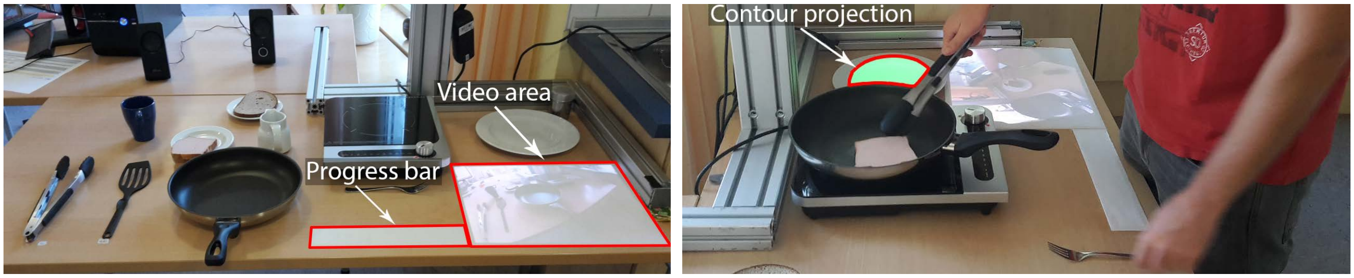
Figure 2: Study setup with pre-portioned ingredients. Auditory feedback is provided via external speakers while visual feedback is delivered by projections.

3.1.1 Auditory Instructions. Auditory instructions are the current communication standard for single cooking steps between tenants and caretakers in sheltered living facilities. Most tenants are not able to read and rely on the verbal exchange of instructions. To provide a similar experience through *in-situ assistance*, we recorded single cooking steps with the voice of a caretaker. External audio speakers, set to a suitable volume, were integrated into the cooking environment (see Figure 2). Cooking instructions were played back with each start of a cooking step. We used a Trust 2.0 speaker setup[2].

3.1.2 Video Instructions. Video instructions were provided by a projector mounted above the cooking environment. The videos were short looped clips, where caretakers showed how to accomplish the next cooking step. The video instructions were projected on a dedicated field right to the cooking area (see Figure 3a). Upon step completion and validation through the Kinect v2, the next instruction video was played back. An Acer K330 was used as projector[3].

3.1.3 Contour Projections. Contour projections were displayed on or around objects which are of interest during the current cooking step. This is accomplished by projecting a green light on different cooking utilities (see Figure 3b). Furthermore, a progress bar below

[2]www.trust.com/en/product/17595-remo-2-0-speaker-set - last access 2019-01-23
[3]www.projectorcentral.com/Acer-K330.htm - last access 2019-01-23



(a) (b)

Figure 3: Visual output modalities of the cooking instruction system. (a): In-situ projections of video instructions and progress bars were displayed inside the cooking area. The projections were placed on white sheets to enhance the visibility. (b): In-situ projection of video instructions and contours which provide visual cues for grasping or placing objects and food.

the hotplate is projected during waiting times (e.g., when frying ingredients). Figure 3a shows the position of the progress bar.

3.2 Methodology and Measures

We employ a within-subject design study including the independent variable *assistance modality* consisting of cooking instruction provided by *in-situ assistance* and instructions provided by *caretaker assistance*. The prepared meal was meatloaf with fried eggs and bread. We have chosen this recipe because it was unknown among the participants. Thus, the overall cooking process was unknown to the participants. The runtime of the experiment was ten days (i.e., two weeks without weekends). Two cooking sessions with two different participants were conducted on each day, where one participant cooked with *caretaker assistance* and another participant with *in-situ assistance*. After the first week, the same participants from the last week were invited on the same weekday again with the contrary assistance modality, i.e., participants who used to cook with *caretaker assistance* were either assisted by *in-situ assistance* and participants who were assisted by *in-situ assistance* used *caretaker assistance* instead. By introducing the break of seven days, we reduce the probability that participants remember the cooking procedure when they cook the same meal again using the contrary instruction modality. In other words, five participants cooked with *in-situ assistance* and another five with *caretaker assistance* during the first week. In the second week, participants that started with *in-situ assistance* were invited to cook with *caretaker assistance*. In contrast, participants which cooked with *caretaker assistance* in the first week used *in-situ assistance* in the second week. Note, that all participants in the second week were already aware of the recipe and the cooking procedure from the first week. The required cooking utilities were placed on predefined positions before the experiment. We ensured a similar positioning of cooking utensils for each session.

We measure the meal preparation time for both assistance modalities to investigate temporal differences between both assistance modalities. We subtracted constant waiting times, such as cooking steps that require frying, from the overall task completion time (see Table 1). By this, individual waiting times between *caretaker assistance* and *in-situ assistance* are removed from the analysis. Overall, four cooking steps facilitated waiting times (i.e., heating oil, frying meatloaf from both sides, and cooking the egg) during one trial. Table 1 shows each cooking step with their accompanied instruction system for *in-situ assistance*. Finally, we conducted semi-structured interviews with the participants about personal preferences in cooking assistance after the experiment.

3.3 Procedure

Prior to the study, we asked for written consent from either the participants or their legal guardian. We conducted the study in a kitchen within a sheltered living facility. We carefully explained the intention of the study to the participants to avoid misunderstandings. Since the system was unfamiliar for the tenants, we made them familiar with the visual and auditory instructions. Furthermore, we showed where the feedback cues were generated to avoid confusion for participants during the study. After being familiar with the system, participants started with the cooking instruction modality according to the balanced Latin square. Prior to the experiment, ingredients were pre-portioned since tenants affected by motoric disorders could not handle the doses by themselves. The experiment started after ensuring all safety arrangements.

Visual instructions were presented alongside auditory feedback for each step. A voice recorded by a caretaker gave instructions on how to perform the current cooking step. Additionally, a video was projected to the right of the cooking area. These videos had a length between two and four seconds that demonstrated how the current cooking step has to be performed. Furthermore, objects of interest were highlighted by contour projections. A Kinect v2 detected whether cooking steps was performed successfully. If a cooking step was conducted correctly, the visual, auditory, and contour instructions proceeded to the next step. The whole cooking procedure comprised 25 cooking steps including four waiting steps to fry the ingredients (see Table 1). Since waiting times may occur during frying steps, short cartoons were projected into the video area. This ensured engagement during waiting times since the participants' concentration may be affected and reducing the likeliness of returning to the cooking task [36]. At the same time, a declining progress bar indicates the remaining waiting time (see Figure 3a). Notes about the interaction between participant and system were recorded during the experiment. A caretaker was always present

Table 1: Single cooking steps with their assigned instruction systems. The steps 7, 11, 13, and 18 consist of waiting times.

Step No.	Cooking Step	Audio	Video	Contour
1	Take pan	X	X	
2	Pan on hotplate	X	X	
3	Start hotplate	X	X	X
4	Set heat	X	X	X
5	Take oil	X	X	
6	Put oil into pan	X	X	
7	Wait until pan is hot	X		
8	Take reacher	X	X	
9	Take meatloaf	X	X	
10	Put meatloaf into pan	X	X	
11	Wait until meatloaf is fried	X		
12	Turn meatloaf	X	X	
13	Wait until meatloaf is fried	X		
14	Put meatloaf on plate	X	X	X
15	Put reacher on table	X	X	
16	Take cup with egg	X	X	
17	Put egg into pan	X	X	
18	Wait until egg is fried	X		
19	Take spatula	X	X	
20	Put egg on plate	X	X	X
21	Turn hotplate off	X	X	
22	Take bread	X	X	
23	Put bread on plate	X	X	X
24	Put salt on meal	X	X	
25	Completion notice	X	X	

during the cooking sessions to ensure the safety of participants. Participants were lauded at the end of the cooking session.

Afterward, participants participated in a semi-structured interview. The participants were asked about their experience when cooking with *caretaker assistance* or *in-situ assistance*. Furthermore, we asked about suggestions for improvements. The answers were recorded and noted by the experimenters. Overall, the study took approximately 30 minutes including meal preparations and post hoc interviews.

3.4 Cooking Equipment

A hotplate and a pan are used to heat the ingredients. We use an induction burner as hotplate for safety reasons. A spatula and a reacher were used to put and turn ingredients in the pan. Finally, fried ingredients were placed on a plate right to the cooking area (see Figure 3). The whole cooking procedure uses pre-portioned ingredients including a piece of meatloaf, salt, eggs, oil, and a piece of bread.

3.5 Results

We analyzed the measures as well as qualitative data collected throughout the study. The results are presented in the following.

3.5.1 Participants. We recruited ten tenants of a sheltered living facility (6 female, 4 male) aged between 24 and 56 years ($M = 40.9$, $SD = 9.93$). The participants had cognitive impairments which limit their ability to process and understand information. None of the participants were affected by dementia. Five caretakers (3 female, 2 male) aged between 19 and 34 years ($M = 26.8, SD = 7.05$) were involved for the *caretaker assistance* condition. Their individual work experience ranged between several months to twelve years. We constantly assigned each caretaker to two participants. We ensured that the same caretaker was cooking with similar participants during the *caretaker assistance* and observed them during *in-situ assistance*.

3.5.2 Cooking Performance. We compare the cooking performance between the conditions *caretaker assistance* and *in-situ assistance* regarding the time participants required to prepare a meal. We process the data by subtracting the fixed waiting times from the overall cooking times of *in-situ assistance* and *caretaker assistance* (see Table 1). *In-situ assistance* comprised a mean waiting time of seven minutes and eight seconds while *caretaker assistance* had a mean waiting time of eight minutes.

First, we statistically analyze the cooking times between *caretaker assistance* and *in-situ assistance* which were collected during both weeks. A Shapiro-Wilk test did not reveal a deviation from normality, $p > .05$. Thus, we submitted the data to a paired samples t-test and found a significant effect between both assistance modalities, $t(9) = 3.628, p = .006, d = 1.147$. Investigating the mean cooking times between both conditions shows longer cooking times for *in-situ assistance* ($M = 236.3, SD = 46.24$) compared to *caretaker assistance* ($M = 228.9, SD = 77.03$). Figure 4 shows the aggregated mean times of the first and second week between both assistance modalities.

Since either five participants cooked with *in-situ assistance* or *caretaker assistance* per week, we separately investigate the cooking times between both conditions for the first and second week. Note that the participants in the second week were aware of the cooking procedure since they already prepared the meal in the first week with the contrary assistance modality. A one-way ANOVA revealed a significant main effect between the cooking times for each week and instruction modality, $F(3, 16) = 3.504, p = .04$. A Tukey post hoc test revealed a significant effect between the use of *in-situ assistance* in the first week and *caretaker assistance* in the second week, $p = .024, d = 2.511$. However, we could not find a significant effect when using *caretaker assistance* in week one and *in-situ assistance* in week two. Furthermore, there is no significant effect when using *in-situ assistance* or *caretaker assistance* in the same week. Participants required more time when using *in-situ assistance* in the first week ($M = 262.8, SD = 34.77$) compared to the second week using *caretaker assistance* ($M = 159.4, SD = 46.7$). *Caretaker assistance* required less time in the first week ($M = 206.8, SD = 70.42$) compared to *in-situ assistance* in the second week ($M = 209.8, SD = 42.96$). Figure 5 shows the separated cooking times of *in-situ assistance* and *caretaker assistance* per week.

3.5.3 Subjective Feedback. We collected qualitative comments from the participants about the experience with traditional *caretaker assistance* and *in-situ assistance*. In the presence of the caretakers, we asked participants if the cooking procedure was pleasant for them. Participants who cooked with *caretaker assistance* and *in-situ assistance* enjoyed cooking. However, one participant stated that

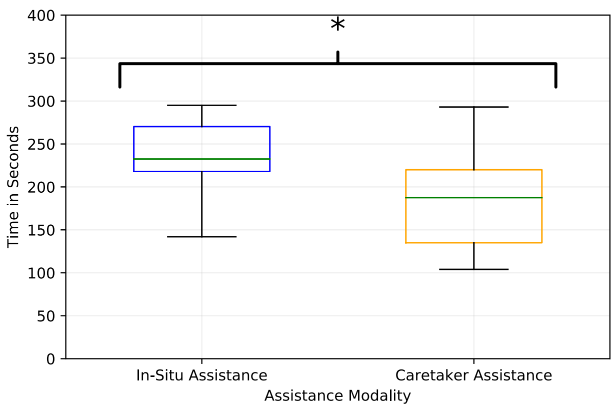


Figure 4: Mean cooking times between *in-situ assistance* and *caretaker assistance* for both weeks. Brackets indicate significant differences.

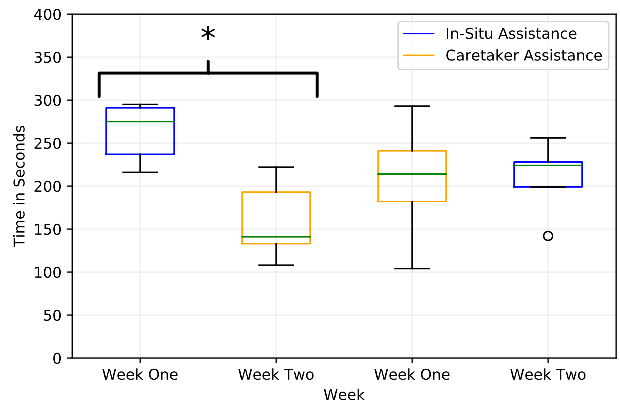


Figure 5: Mean cooking times for *in-situ assistance* and *caretaker assistance* for each week. Participants that started with *in-situ assistance* had higher cooking times in the second week using *caretaker assistance*.

"[. . .] *the videos were not helpful*" (P4) while others found that the "[. . .] *videos were funny*" (P9) and that "[. . .] *the contour projections were engaging*" (P7).

Furthermore, we asked participants if they found the visual and auditory feedback helpful. All participants except one (P4) found the projected videos helpful. Four participants stated that they noticed them when they were stuck in the cooking process (P2, P4, P5, P10). The sound was perceived by all participants positively except one participant who stated that "*The voice was not helpful, the videos helped me more.* " (P9).

Finally, we asked if the participants could imagine integrating such a system into their daily communal cooking procedure. All participants except one (P8) agreed with an integration of the system into their daily life. However, one participant mentioned the importance of social interaction during cooking activities (P3). One of the participants stated, that the system "[. . .] *provided more safety when cooking alone*" (P2). One participant preferred to cook with a caretaker instead of the system (P8).

3.5.4 Qualitative Observation. We observed the interaction between the tenant and the assistive system in the kitchen. We noted, that all participants were able to perform most of the cooking steps by listening to the voice. Video instructions, which were displayed in every cooking step, were perceived when the voice instruction was not understood. The tenants are used to voice-driven instructions since cooking instructions are communicated verbally during the cooking process. A similar observation was found in the perception of the progress bar, which was noticed after they were hinted by the experimenter or caretaker. Four participants required help to understand the system before conducting the first cooking steps. Afterward, the cooking process was guided by the system without interruptions.

4 DISCUSSION

We evaluated an assistive cooking system with cognitively impaired in a sheltered living facility. In the following, we discuss the results of our study.

4.1 Cooking Performance and Learning Effect

Overall, we measured longer meal preparation times using *in-situ assistance* compared to *caretaker assistance*. However, we find that the cooking times with *caretaker assistance* in the second week improves significantly when *in-situ assistance* was employed in the first week. Since cooking instructions are usually conveyed verbally, the visual feedback generated by in-situ assistance might complement the cognitive processing of instructions. Therefore, a combination of visual and auditory cooking instructions could result initially in a longer cooking procedure, but can also contribute to an improvement in understanding the cooking process. Furthermore, a learning effect can eventuate as a result of using *in-situ instructions*. We could not observe this effect when starting with *caretaker assistance* in the first week and continuing with *in-situ assistance* in the second week. This assures the hypothesis that visual feedback can be used as complementary feedback modality to help people with cognitive impairments to remember or understand complex cooking instructions.

4.2 Feedback Modalities

From our observations, we find that most participants could handle simple cooking instructions using auditory feedback. Video and contour projections were considered during waiting times or more complex steps, such as turning ingredients in the pan. These results conform with previous research [21], where auditory instructions are preferred to convey and process information. However, most participants considered video and contour instructions useful to understand details although not always needed. We believe that video and contour instructions supplement auditory feedback for rather complex cooking instructions.

4.3 Subjective Perception

We asked caretakers and people with cognitive impairments about their perception of cooking with assistive technologies. The responses were positive by both caretakers and tenants. Participants stated that visual and auditory feedback complement each other in terms of understanding the current cooking step. Since tenants are usually not able to cook without *caretaker assistance*, most of the participants enjoyed their autonomy during the cooking process using *in-situ assistance*. This indicates that suitable feedback content is a critical factor to consider when conducting further research on assistive technologies in private and sheltered living facilities.

4.4 Limitations

We are aware that our research is prone to a number of limitations. We did not consider the individual cognitive impairment per participant. Prior to the study, we ensured that the level of cognitive impairment was similar for each participant. However, assessments to estimate the individual level of cognitive impairment are conducted irregularly. As mental abilities develop further, the assessment may become irrelevant regarding the individual impairment. Furthermore, we did not consider the individual level and type of cognitive impairment in our study design. Thus, the results may not be generalizable to people that are affected by other cognitive impairments, such as dementia or motoric disorders.

For safety reasons, a caretaker was always present during the course of the study regardless of the cooking assistance modality. Thus, we did not investigate how individual behavior may change when a caretaker is not present. Past studies [22] have shown that tenants possess more self-confidence when familiar persons are nearby. Therefore, it is not clear how people with cognitive impairment interact with assistive technologies in their home environments when caretakers are not nearby.

4.5 Future Work

In future work, we plan to conduct a large-scale long-term study for investigating possible learning effects. Therefore, we plan to integrate an adaptive version of *in-situ assistance* in a sheltered living facility. This adaptive system will provide feedback when errors in the cooking procedure are detected instead of providing continuous support. The amount of *in-situ assistance* will be reduced over time to investigate the degrees of necessary assistance. Based on the results from the long-term study, we will deploy the cooking system into a kitchen of an independent living apartment. By this, we gain insights into the feasibility of assistive technologies in home environments of people with cognitive impairments. Furthermore, we will test different algorithmic approaches for teaching new recipes. This enables caretakers to incorporate their own sequence of cooking instructions, which can be tailored for individual cooking preferences and disabilities.

5 CONCLUSION

In this paper, we present a study which compares *caretaker assistance* and *in-situ assistance* during cooking for people with cognitive impairments. We find that *in-situ assistance* requires more meal preparation time in the first week compared to *caretaker assistance*. However, the cooking performance of *caretaker assistance* improves fundamentally when the cooking procedure was conducted with *in-situ assistance* beforehand. Through semi-structured interviews, we find that the visual and auditory feedback provided by *in-situ assistance* is well accepted among tenants. We believe that such assistive technologies can be used in the future to compensate for cognitive impairments. Learning how to accomplish daily life tasks by assistive technologies goes a step towards independent living for people with cognitive impairments.

6 ETHICS STATEMENT

The research presented in this paper underwent the ethical approval procedures required by the conducting institution. Ethical approval from the appropriate government authority was obtained along with the consent of the sheltered living facility.

7 ACKNOWLEDGEMENTS

This work is supported by the German Federal Ministry of Education and Research as part of the project KoBeLU (Grant No. 16SV7599K). We thank Benjamin Treptow and Peter Eßlinger from the GWW - Gemeinnützige Werkstätten und Wohnstätten GmbH for their great help in organizing the study.

REFERENCES

[1] Amaya Arcelus, Megan Howell Jones, Rafik Goubran, and Frank Knoefel. 2007. Integration of smart home technologies in a health monitoring system for the elderly. In *Advanced Information Networking and Applications Workshops, 2007, AINAW'07. 21st International Conference on*, Vol. 2. IEEE, 820–825. https://doi.org/10.1109/AINAW.2007.209

[2] Rubén Blasco, Álvaro Marco, Roberto Casas, Diego Cirujano, and Richard Picking. 2013. A smart kitchen for ambient assisted living. *Sensors (Basel, Switzerland)* 14, 1 (2013), 1629–1653. https://doi.org/10.3390/s140101629

[3] Leonardo Bonanni, Chia-Hsun Lee, and Ted Selker. 2005. Attention-Based Design of Augmented Reality Interfaces. (2005). http://vs.inf.ethz.ch/edu/SS2005/DS/papers/projected/bonanni-chi05.pdf

[4] Bruno Bouchard, Sylvain Giroux, and Abdenour Bouzouane. 2006. A smart home agent for plan recognition of cognitively-impaired patients. *Journal of Computers (Finland)* 1, 5 (2006), 53–62. https://doi.org/10.4304/jcp.1.5.53-62

[5] SJ Brownsell, David A Bradley, R Bragg, P Catlin, and J Carlier. 2000. Do community alarm users want telecare? *Journal of Telemedicine and Telecare* 6, 4 (2000), 199–204. https://doi.org/10.1258/1357633001935356

[6] Yao-Jen Chang, Ya-Shu Kang, Yao-Sheng Chang, and Hung-Huan Liu. 2015. ARCoach 2.0: Optimizing a Vocational Prompting System Based on Augmented Reality for People with Cognitive Impairments. In *Proceedings of the 17th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '15)*. ACM, New York, NY, USA, 313–314. https://doi.org/10.1145/2700648.2811354

[7] Pei Yu Chi, Jen Hao Chen, Hao Hua Chu, and Jin Ling Lo. 2008. Enabling calorie-aware cooking in a smart kitchen. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 5033 LNCS (2008), 116–127. https://doi.org/10.1007/978-3-540-68504-3-11

[8] Pei-Yu Peggy Chi, Hao-Hua Chu, Jen-hao Chen, and Bing-Yu Chen. 2007. Enabling nutrition-aware cooking in a smart kitchen. *Persuasive 2008, Lncs 5033* (2007), 116–127. https://doi.org/10.1145/1240866.1241003

[9] Karen L Courtney. 2008. Privacy and senior willingness to adopt smart home information technology in residential care facilities. (2008). https://doi.org/10.3414/ME9104

[10] Karen L Courtney, George Demeris, Marilyn Rantz, and Marjorie Skubic. 2008. Needing smart home technologies: the perspectives of older adults in continuing care retirement communities. (2008).

[11] George Demiris, Brian K Hensel, Marjorie Skubic, and Marilyn Rantz. 2008. Senior residents' perceived need of and preferences for "smart home" sensor technologies. *International journal of technology assessment in health care* 24, 01 (2008), 120–124. https://doi.org/10.1017/S0266462307080154

[12] Markus Funk, Andreas Bächler, Liane Bächler, Oliver Korn, Christoph Krieger, Thomas Heidenreich, and Albrecht Schmidt. 2015. Comparing Projected In-Situ Feedback at the Manual Assembly Workplace with Impaired Workers. In *Proceedings of the 8th International Conference on PErvasive Technologies Related to Assistive Environments*. ACM, New York, NY, USA. https://doi.org/10.1145/2769493.2769496

[13] Markus Funk, Andreas Bächler, Liane Bächler, Thomas Kosch, Thomas Heidenreich, and Albrecht Schmidt. 2017. Working with Augmented Reality? A Long-Term Analysis of In-Situ Instructions at the Assembly Workplace. In *Proceedings of the 10th ACM International Conference on PErvasive Technologies Related to Assistive Environments*. ACM, New York, NY, USA. https://doi.org/10.1145/3056540.3056548

[14] Markus Funk, Sven Mayer, and Albrecht Schmidt. 2015. Using In-Situ Projection to Support Cognitively Impaired Workers at the Workplace. In *Proceedings of the 17th international ACM SIGACCESS conference on Computers & accessibility*. ACM. https://doi.org/10.1145/2700648.2809853

[15] Markus Funk and Albrecht Schmidt. 2015. Cognitive Assistance in the Workplace. *Pervasive Computing, IEEE* 14, 3 (July 2015), 53–55. https://doi.org/10.1109/MPRV.2015.53

[16] Atsushi Hashimoto, Naoyuki Mori, Takuya Funatomi, Yoko Yamakata, Koh Kakusho, and Michihiko Minoh. 2008. Smart Kitchen : A User Centric Cooking Support System. *Proceedings of IPMU* (2008), 848–854. http://www.mm.media.kyoto-u.ac.jp/research/doc/841/112-Hashimoto.pdf

[17] Clare J. Hooper, Anne Preston, Madeline Balaam, Paul Seedhouse, Daniel Jackson, Cuong Pham, Cassim Ladha, Karim Ladha, Thomas Plötz, and Patrick Olivier. 2012. The French Kitchen: Task-based Learning in an Instrumented Kitchen. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing (UbiComp '12)*. ACM, New York, NY, USA, 193–202. https://doi.org/10.1145/2370216.2370246

[18] Oliver Korn, Markus Funk, and Albrecht Schmidt. 2015. Design Approaches for the Gamification of Production Environments. A Study Focusing on Acceptance. In *Proceedings of the 8th International Conference on PErvasive Technologies Related to Assistive Environments*. ACM, New York, NY, USA. https://doi.org/10.1145/2769493.2769549

[19] Oliver Korn, Markus Funk, and Albrecht Schmidt. 2015. Towards a Gamification of Industrial Production. A Comparative Study in Sheltered Work Environments. In *Proceedings of the 7th ACM SIGCHI Symposium on Engineering Interactive Computing Systems*. ACM, New York, NY, USA. https://doi.org/10.1145/2774225.2774834

[20] Thomas Kosch, Yomna Abdelrahman, Markus Funk, and Albrecht Schmidt. 2017. One Size Does Not Fit All: Challenges of Providing Interactive Worker Assistance in Industrial Settings. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers (UbiComp '17)*. ACM, New York, NY, USA, 1006–1011. https://doi.org/10.1145/3123024.3124395

[21] Thomas Kosch, Romina Kettner, Markus Funk, and Albrecht Schmidt. 2016. Comparing Tactile, Auditory, and Visual Assembly Error-Feedback for Workers with Cognitive Impairments. In *Proceedings of the 18th international ACM SIGACCESS conference on Computers & accessibility*. ACM. https://doi.org/10.1145/2982142.2982157

[22] 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 (CHI '18)*. ACM, New York, NY, USA, Article 271, 12 pages. https://doi.org/10.1145/3173574.3173845

[23] Li Jiang, Da-you Liu, and Bo Yang. 2004. Smart home research. *Proceedings of 2004 International Conference on Machine Learning and Cybernetics (IEEE Cat. No.04EX826)* 2, August (2004), 659–663. https://doi.org/10.1109/ICMLC.2004.1382266

[24] Valeria Manera, Pierre-David Petit, Alexandre Derreumaux, Ivan Orvieto, Matteo Romagnoli, Graham Lyttle, Renaud David, and Philippe H. Robert. 2015. 'Kitchen and cooking,' a serious game for mild cognitive impairment and Alzheimer's disease: a pilot study. *Frontiers in Aging Neuroscience* 7 (2015), 24. https://doi.org/10.3389/fnagi.2015.00024

[25] Alex Mihailidis, Jennifer N. Boger, Tammy Craig, and Jesse Hoey. 2008. The COACH prompting system to assist older adults with dementia through handwashing: An efficacy study. *BMC Geriatrics* 8, 1 (07 Nov 2008), 28. https://doi.org/10.1186/1471-2318-8-28

[26] Tina Minkowitz. 2006. The United Nations Convention on the Rights of Persons with Disabilities and the right to be free from nonconsensual psychiatric interventions. *Syracuse J. Int'l L. & Com.* 34 (2006), 405.

[27] Kenzaburo Miyawaki, Mutsuo Sano, Syunichi Yonemura, and Mihoko Matsuoka. 2009. A Cooking Support System for People with Higher Brain Dysfunction. In *Proceedings of the ACM Multimedia 2009 Workshop on Multimedia for Cooking and Eating Activities (CEA '09)*. ACM, New York, NY, USA, 47–52. https://doi.org/10.1145/1630995.1631004

[28] Patrick Olivier, Guangyou Xu, Andrew Monk, and Jesse Hoey. 2009. Ambient Kitchen: Designing Situated Services Using a High Fidelity Prototyping Environment. In *Proceedings of the 2Nd International Conference on PErvasive Technologies Related to Assistive Environments (PETRA '09)*. ACM, New York, NY, USA, Article 47, 7 pages. https://doi.org/10.1145/1579114.1579161

[29] World Health Organization. 2015. *World report on ageing and health*. World Health Organization.

[30] Robert Perneczky, Corina Pohl, Christian Sorg, Julia Hartmann, Katja Komossa, Panagiotis Alexopoulos, Stefan Wagenpfeil, and Alexander Kurz. 2006. Complex activities of daily living in mild cognitive impairment: conceptual and diagnostic issues. *Age and Ageing* 35, 3 (2006), 240–245. https://doi.org/10.1093/ageing/afj054

[31] Martha E. Pollack. 2005. Intelligent Technology for an Aging Population: The Use of AI to Assist Elders with Cognitive Impairment. *AI Magazine* 26, 2 (2005), 9. https://doi.org/10.1609/AIMAG.V26I2.1810

[32] 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 (IoT'16)*. ACM, New York, NY, USA, 169–170. https://doi.org/10.1145/2991561.2998471

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

[34] Emmanuel Stip and Vincent Rialle. 2005. Environmental cognitive remediation in schizophrenia: Ethical implications of "smart home" technology. *The Canadian Journal of Psychiatry* 50, 5 (2005), 281–291. https://doi.org/10.1177/070674370505000509

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

[36] Angela K Troyer and Kelly J Murphy. 2007. Memory for intentions in amnestic mild cognitive impairment: Time-and event-based prospective memory. *Journal of the International Neuropsychological Society* 13, 2 (2007), 365–369.