

Designing and Testing a Connected System for Heating Delivered Food for Elderly People

Introducing the AAL project PREPARIO

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Abstract— Existing meal preparation solutions are inadequate for many elderly people who struggle to reheat their delivered meals. It is common for meals to be over- or under-heated, which can ruin the meal itself as well as the eating experience. In some cases, this leads to malnutrition and serious illness, and in other cases, caregivers are required to assist with food preparation on a daily basis, time that could be better spent with the client and a major financial burden to society. In addition, stakeholders, such as caregivers, have limited means of obtaining feedback from older people about potential problems with meal preparation, which prevents critical and efficient support. The Active and Assisted Living Joint Project (AAL JP) PREPARIO aims to develop a solution that enables seniors to prepare their meals safely and independently at home, with external digital monitoring to enable efficient care. The solution consists of an innovative microwave oven with wireless temperature control that enables fully automated heating of delivered meals to the optimal serving temperature. The entire heating process is supported by a digital voice assistance platform - "Emma" - and a Smart Living Data Space that collects all data relevant to the food preparation process and provides structured reports for caregivers and service providers for closer monitoring and support.

Keywords: *Smart Home; Food Preparation; User centered Service Design.*

I. INTRODUCTION

The AAL project PREPARIO [1] aims to develop a connected and automated food preparation platform that integrates a microwave oven, a temperature probe, and a voice assistant, and connects these devices to a smart home

environment that collects and visualizes data on usage, errors, and questionnaire results.

Despite the widespread adoption of the microwave oven since its invention over 70 years ago, its capabilities have remained largely unchanged and far from innovative compared to other household appliances. Most functions rely heavily on manual process control and prior user knowledge/experience due to the lack of temperature sensing capabilities. Now, more sophisticated solutions are emerging, with features that make meal preparation easier, such as the ability to scan package barcodes (GE Appliances' Scan-To-Cook technology [2]), use voice-activated commands (Whirlpool's Smart Over-the-Range Microwave [3]), and built-in sensors (Breville's Breville Quick Touch with Sensor iQ™ [4]) to tell you how to cook meals and when they are done. However, although these are interesting and innovative products, they are not suitable or tailored to the senior population. They often require a high level of technological knowledge and special connections to other devices that are simply not attractive or user-friendly for older adults. They are also considered premium devices and are often priced well above the average market price, making them unaffordable for most people. Importantly, they use non-ideal sensors (e.g., humidity or infrared sensors) to estimate when the meal is "ready" and require extensive user input, such as the type of food to be heated and the weight of the food. Such solutions are state of the art, but due to the lack of reliable temperature sensing, the heating result can vary widely and may not directly correspond to a "ready to eat" meal, as it may be too hot and far from the appropriate serving temperature. Therefore, in our opinion, even the

emerging more sophisticated microwaves are not suitable for integration into current food delivery services and cannot offer an improvement to existing systems for older adults.

The PREPARIO system is designed to allow independent end-users to heat their pre-prepared and home-delivered meals to an appropriate and safe temperature for consumption in a fully automated manner. The interface of the microwave oven has been modified to be as easy to use as possible, i.e. only one button for "start", thus reducing the barriers to use. In addition, the heating process uses a developed and validated algorithm aimed at ensuring that the food is at the right temperature throughout (and not just on the surface or in the core). Users can continue with their activities and are notified by a voice interaction device when their meal is ready. A survey linked to the system can be answered via an easy-to-use interface on a tablet. The results are stored in a central database along with the data sent by the microwave. This provides a dashboard view of the microwave's usage and the user's well-being. For example, caregivers or family members can monitor whether hot meals have been prepared as expected.

The project was initiated by Senserna A/S - the company that invented the world's first temperature probe for microwave ovens - to further improve the idea and evaluate the prototype with partners from the technology, science and care sectors.

At a very early stage, a number of activities were carried out to gather requirements for the concept. The first action was a stakeholder questionnaire addressed to 81 social institutions with the aim of deepening the knowledge of the targeted primary end-users, their needs and expectations. This was followed by a user-centered design process for the applications to be implemented. Three co-creation workshops provided feedback on the prototype, its possible barriers, limitations and opportunities. The desire was expressed to further promote integration with solutions available on the market and to expand the user group to include people with cognitive or physiological disabilities.

The solution is being tested in a testbed environment with caregivers and elderly people in care centers in two trial phases. One trial has been completed and the other is ongoing. It turns out that most people are able to use the microwave to heat their meals and are almost always satisfied with the temperature of the food. The data from the questionnaires and the system parameters provide important technical information about the state and use of the solution. These results and the general feedback help to further improve the idea and its implementation.

This paper gives an insight into the methods used and the results obtained from the involved end-users and stakeholders, with an outlook on how the final product could become an integral part of care and independent living. The rest of the paper is structured as follows. Section 2 describes the methods used to develop the solution, which is evaluated in the project with trial runs, co-creation workshops and stakeholder questionnaires, as outlined in Section 3. The paper ends with a conclusion and outlook in Section 4.

II. METHODS

The project uses a user-centered approach to identify barriers, usability issues, and related problems (such as time efficiency for social workers) in order to develop a solution that addresses these shortcomings in the process of heating home-delivered meals. From there, user involvement will continue throughout all phases of the project to ensure optimal acceptance. The resulting prototypes will be presented to and tested by the target user groups and all feedback will be considered in the following phases. The general steps for this process are listed below:

1. Interviews with end users and subject-matter experts in person and through written surveys.
2. Hands-on experience: Heating a meal, eating and tasting the meal, evaluating the experience.
3. Identify and list problems.
4. Brainstorm technical solutions.
5. Define technical solutions to develop and test.
6. Define tests to evaluate solutions.
7. Evaluate and share results.

A. *What problem our solution is trying to solve*

Preparing food is one of the most important Instrumental Activities of Daily Living (IADLs) and helps people maintain a sense of self-worth and self-efficacy [5][6]. When cooking and obtaining the materials for this task becomes more difficult due to circumstances and changes in mobility, delivered meals are often a solution.

The microwave oven is a popular choice for heating pre-prepared meals. One of the major advantages is that a meal can be heated directly in the meal packaging, reducing the need for cleaning. Another advantage is the heating speed of only 4-6 minutes for a cold meal from the refrigerator that would normally take 25-30 minutes to heat in a conventional oven.

However, the microwave oven also has some drawbacks:

1. Complicated user interface - A microwave oven can have many different functions and automatic heating programs. Some interfaces have more than 20 buttons and only a simple 7-segment Light Emitting Diode (LED) display. Users are often unaware of the wealth of features and/or do not use them [7].
2. Lack of temperature control - The microwave oven can be viewed as a black box where the temperature cannot be measured and controlled during meal preparation. Therefore, the heating result is based on a trial and error approach, where the user guesses the heating time for a certain power setting, often resulting in suboptimal heating results.
3. Uneven heating - The heating efficiency of microwaves vary with the size, consistency and type of food that is heated. This, combined with the microwave's hot and cold spots, can result in large temperature differences in the heated food. In other words, a meal that appears searing hot on the outside may be cold or even frozen in the center.
4. Zero Connectivity - Home appliances have benefited from the tremendous technological developments of the past few decades. However, the vast majority of microwave

manufacturers have not embraced new technology and do not offer any form of connectivity. This is a current area of research and several studies are looking at making the kitchen smarter for older adults [8].



Figure 1. The adapted microwave and a meal with the probe inserted (Solution 1).



Figure 2. The innovative tray with built in sensors (Solution 2).

B. Description of the system and its functions

Senserna A/S has developed a revolutionary temperature sensor technology for microwave ovens that has the potential to mitigate the above mentioned disadvantages. With this new possibility in mind, two interesting solutions have been developed to improve the preparation of home delivered meals.

Solution 1 is a special microwave oven designed to automatically heat delivered meals to a pre-defined target temperature of 75°C using a novel probe-based temperature sensing and control mechanism. A Bluetooth module is built into the microwave for wireless transmission of measurable system parameters related to the heating process. The probe contains five temperature sensors and sends the average of the sensors to the microwave and via Bluetooth to devices beyond. The connected system can then display and respond to the current temperature. Errors can also be relayed and dealt with in this way. Figure 1 shows the system as it was used in the first test phase.

Solution 2 is a probe-less temperature sensing solution (see Figure 2), consisting of a dedicated meal tray with seamlessly integrated temperature sensors. This would be the most user friendly solution imaginable. The only thing a user would have to do to heat a meal is to take a meal from the refrigerator and place it in a special tray before placing it in the microwave. From there, the microwave would sense the meal and automatically heat it without any further user interaction.

This smart microwave system allows for connections to other devices, and for this project, the personal smart voice assistant “Emma” was used. The voice assistant receives the status of the meal and the heating process from the microwave via Bluetooth, and can, for example, issue a reminder when the food is ready to be picked up. This extends the scope of the “Emma” product, which functions as a connected voice assistant for the smart home, performing various tasks such as setting scenes, starting music, reminding people to take their medication and so on. “Emma” connects to the user’s wireless network and transmits all information from the microwave to an intelligent digital database, which then allows remote access and visualization of the collected data. Unfortunately, this product has been discontinued while the project was ongoing (April 2024).

III. TRIALS, CO-CREATION AND FINDINGS

The goal of the first trial was to have 30 primary end users and 5 secondary end users (caregivers) test the solution with the connected microwave and temperature probe and provide feedback via a questionnaire and written observations of user behavior. The information collected during the trial was completely anonymous, and there was no way to link the responses and observations to a specific end-user.

The procedure of trial 1 was as follows:

1. Welcome the end-user and move to the trial location.
2. Introduce the user to the trial.
3. Introduce the user to the assessment app.
4. Begin the trial by answering questions via the assessment app.
5. Let the user select a meal.
6. Introduce the user to the microwave oven with automatic heating functionality.
7. Let the user warm a meal using microwave oven.
8. Let the user taste/eat the meal.
9. End the trial by answering more questions via the assessment app.
10. End of trial.

The trial was performed with one end-user at a time and a trial instructor present through the entire trial for support and taking notes.

The second trial will take place in July 2024 and will follow the same procedure as described above and have the same test users (if available). The trial will test the improved system with the connected audio system together with the tablet for the pre- and post-meal questionnaires.

A. Co-Creation Workshops

At the beginning of the project, two different questionnaires were carried out by the Municipality of Vila Nova de Cerveira to answer the questions posed by the project team: an online questionnaire addressed to 76 social institutions in the district of Viana do Castelo with the aim of deepening the methods used to deliver meals at home.

The second questionnaire, addressed to social institutions in the municipality of Vila Nova de Cerveira, aimed to deepen the knowledge about the end users, namely the characterization of the users (how many, age, average pension, mental and physical illnesses, situation of social and geographical isolation) and their needs and expectations.

As the project progressed, stakeholders and representatives of the target groups were invited to workshops to learn more about the current situation of elderly care and food delivery.

An online workshop was offered to Austrian stakeholders and two face-to-face workshops were held in Portugal. In addition, an international workshop with representatives from all participating countries will take place at the end of April 2024.

1) Online Workshop Austria

In Austria, a stakeholder workshop was held as an online videoconference with a total of 9 participants. Four of them were not involved in the project and represented the stakeholders. Two of them work in the management of a care organization, one in the management of a medical aid organization in the field of home care for the elderly, and one person comes from academia in the field of care research. The participating stakeholders are in close contact with the target primary user group. They know their needs, their living conditions and their daily structures.

The workshop started with an introduction of the participants followed by a presentation of the project. A video of the prototype solution was used to demonstrate how it works in a real-life scenario. The video was recorded by the partner in Portugal and showed one of their clients using the microwave to heat a meal. Another video demonstrated the use and capabilities of the EMMA smart home system. The presentation was followed by a moderated discussion with questions on (i) usage and benefits, (ii) functionality, and (iii) markets, business opportunities and revenue streams.

Statements about **usage and usefulness**:

- New microwaves are often no more user-friendly than old ones because they have so many buttons it becomes too complicated for people to use.
- The system should be a complete service, possibly with instructions to prepare a complete meal from the ingredients.
- Not sure how useful the data about the smart home system is. The dashboard data shows only a small excerpt from a whole day of a person. Other data will be completely missing, e.g., when a person eats somewhere else.

Statements about **functionality**:

- Integration with existing smart home solutions, e.g., Amazon Alexa is desired as some households already have those systems in use.
- Clients living in a care organization have a fixed daily routine; a system that reminds them would be helpful, for example when to start preparing meals.
- One care organization already uses a similar product for easy cooking (Thermomix®). It works well for their clients in assisted living. It gives people independence and self-efficacy. In addition, virtual voice assistants (e.g., Amazon Alexa) are in use and it works well for cognitive impaired people.
- A smart home system should speak in the voice of a familiar person; this would make things much easier.

Statements about **markets, business opportunities and revenue streams**:

- It is a niche product, but demand is possible.
- For many people a product like this is not top priority, they have other more fundamental problems to solve every day, e.g., mobility (wheel chair, stair lift, etc.). It can be seen as a luxury item.
- Possible new target groups: cognitive impaired or disabled persons.
- Possible business models: rent or buy.
- Target groups for selling this service could be:
 - Private customers who buy the microwave oven or the service.
 - Care organization who buy the microwave oven or the service and then rent it to their clients.
 - A subscription from a food delivery service, with the microwave oven included for free (or for a reduced price).

More co-creation workshops were held as face-to-face meetings by the two partners in Portugal. 17 people attended the workshop in Vila Nova de Cerveira (November 23rd, 2023) and 17 people attended the workshop in Lisbon (November 16th, 2023) - a total of 34 people took part in the discussions. Each workshop was attended by three people linked to the project who facilitated the session.

2) Workshop at Vila Nova de Cerveira (Portugal)

In view of the territorial context and the system of providing meals to the elderly through the Home Care Service in the Alto Minho region and in Lisbon, representative bodies of the most diverse sectors directly or indirectly involved in this service, on the one hand, and companies and organizations from the most diverse sectors of society, on the other hand, were invited to these workshops.

Thus, political representatives from local authorities, public social services, public health services, social institutions and private companies providing care for the elderly, companies in the food sector and new technologies for the elderly, and a company in the plastics processing sector were invited to participate in this workshop.

Specifically, the workshop in Cerveira was attended by a diverse group, including three participants as political representatives of local authorities, one from a public social service, two from public health services, two from social institutions, four people from private companies providing care for the elderly, one person from a company in the food sector, two from companies developing new technologies for the elderly, and one person from a company in the plastics processing sector.

At the beginning, the participants received an explanation of the workshop and the topics to be covered. The PREPARIO project was presented with its service model and technical components. A microwave prototype with a sensor probe was used to demonstrate the heating process.

During the workshop the following topics were discussed and the answers of the participants were recorded:

- In response to the home meal distribution service currently provided, please identify: 1 POSITIVE factor & 1 NEGATIVE factor.
- From the PREPARIO solution presented - Identify the most relevant function.
- From the PREPARIO solution presented: - Identify the biggest problem.
- General opinion on PREPARIO solution that we present to you.
- How much would you pay for the PREPARIO solution.
- How do you imagine the PREPARIO solution will be able to reach customers (from home delivery of meals to heating).

In conclusion, the provision of basic meals is a very important factor in giving people equal access to fresh, healthy and balanced meals and in facilitating their daily lives. The problems identified were congruent with those identified at the outset of the project: lack of control over the heating process, difficulties in handling food containers and uneven temperatures, and lack of feedback.

What the PREPARIO project offers was seen as valuable because it is simpler, with only one button, with acoustic reminders to take out the food, and with the possibility of giving feedback directly by voice or through a large touch interface. Issues identified were: reluctance to use a new device, the training that might be required, the cost of the system, the possibility of losing the probe as it is not connected to the microwave, and the hygiene of the probe. Stakeholder input also led to the conclusion that delivering cold meals would simplify the logistics of meal delivery and would require fewer delivery trips throughout the week compared to delivering hot meals.

3) Workshop in Lisbon (Portugal)

This workshop was also attended by 17 people invited to discuss aspects of the daily life and food preparation of adults aged 65+. The participants came from a variety of relevant backgrounds, namely: different departments of Santa Casa da Misericórdia de Lisboa, including the Department of Health, the Department of Studies and Strategic Planning, the Department of Intervention with

Vulnerable Public, the Department of Technical Management and Monitoring, the Mission Unit - Lisbon, City of All Ages Program and the Department of Entrepreneurship and Social Economy. Also present were private institutions of social solidarity, representatives of the local council and of a food service company.

After the presentation of the project and its partners, the participants were invited to ask questions, to ask for clarifications and, last but not least, to give their feedback. This was divided into sections:

Current response to home-delivered meals for heating: participants were asked to identify one positive and one negative factor in the current system/service, followed by a debate among all participants on the current response to home-delivered meals.

PREPARIO solution: Everyone was asked to identify the most relevant function and the biggest problem in the PREPARIO solution, followed by a debate among all participants about the equipment under development.

Business Plan for the PREPARIO solution: Each of the participants was asked to identify how much they would pay for the PREPARIO solution, in an assigned value logic, followed by a debate among all the participants on what possible business model would make the equipment available to users/clients

Overall, the current situation was described with the positive points of guaranteed meals of good quality and dietary value, the facilitation of autonomous food intake; negative points were the failure points with autonomous heating leading to over or undercooked meals, the limited variety and environmental issues with packaging, among others.

The PREPARIO solution was seen as simple and fail-safe, with the additional data for monitoring as an advantage in care contexts, but the cost of the adapted microwave, the possibility of misplacing the probe and the uncertain acceptance of new technology were seen as risks. It was also mentioned that the target group is quite specific in that the person using it must be physiologically able to do so, it is not an enhanced asset for blind, bedridden or cognitively impaired people.

The question about pricing and business models was answered that prices would have to be kept quite low, and in the best case the microwave would be offered by a care organization, a municipality or the food supplier, and the costs would be covered by the general fees for services.

B. Findings

The overall findings from the co-creation efforts and the feedback from the observed heating processes and the tailored questionnaires were that the technology has great potential and that the heating process was, in most cases, very satisfying. The combination of questions about the quality of the food and the experience of heating it was helpful and not intrusive. The concerns raised, particularly about losing the probe and its hygiene, are being addressed in the second prototype with a specially designed food

container with built-in temperature sensors. This will be tested in the second trial in July.

IV. CONCLUSION

The availability of food delivery services is considered important, especially in the aftermath of the COVID-19 pandemic, when people were even more homebound than before. However, food safety, food preparation safety and food quality remain issues in this context [9][10]. The PREPARIO system offers elderly people living independently a solution for heating delivered meals in an easy and safe way. Trials with the target groups showed promising results and very good acceptance. The additional functionality of monitoring the use of the system, and thus the data on suspected food intake, is considered valuable by caregivers and related parties, as determined during the co-creation workshops with stakeholders and care organizations, as well as during the trials with caregivers. Further trials with the sensorized food tray will provide additional insights and help improve the system for market readiness. By removing the burden of assisting with food preparation, caregivers or informal caregivers such as family members can focus on other tasks and use their time more efficiently.

We believe the end product could become an integral part of caregiving and independent living.

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REFERENCES

- [1] <https://www.aal-europe.eu/projects/prepario/> [retrieved May 2024].
- [2] <https://geappliancesco.com/blog/ge-appliances-smart-wall-ovens-and-ranges-offer-a-new-way-for-consumers-to-discover-new-recipes-cook-and-shop/> [retrieved May 2024].
- [3] https://producthelp.whirlpool.com/Connected_Appliances/Product_Info/Connected_Support/Scan_to_Cook_Feature_-_How_Does_it_Work%3F [retrieved May 2024].
- [4] <https://www.breville.com/us/en/products/microwaves/bmo850.html> [retrieved May 2024]
- [5] C. H. Hestevik, M. Molin, J. Debesay, A. Bergland, and A. Bye, "Older patients' and their family caregivers' perceptions of food, meals and nutritional care in the transition between hospital and home care: a qualitative study", *BMC nutrition* vol. 6 11. 18 Mar. 2020, doi:10.1186/s40795-020-00335-w.
- [6] J. A. Jackson, A. Branscum, A. Tang, and E. Smit, "Food insecurity and physical functioning limitations among older U.S. adults", *Preventive Medicine Reports*, vol. 14, 100829, ISSN 2211-3355, 2019, <https://doi.org/10.1016/j.pmedr.2019.100829>.
- [7] M. Zallio, P. Kelly, M. Jakuska, H. Rifai, and D. Berry, "Design of a community-supported CapAble microwave system for people with intellectual and physical disabilities", In: Cavallo, F., Marletta, V., Monteriù, A., Siciliano, P. (eds) *Ambient Assisted Living. ForItAAL 2016. Lecture Notes in Electrical Engineering*, vol 426. Springer, Cham., 2017, https://doi.org/10.1007/978-3-319-54283-6_5.
- [8] M. Zallio, P. Kelly, B. Cryan, and D. Berry, "A co-Design approach to develop a smart cooking appliance. Applying a Domain Specific Language for a community supported appliance", arXiv preprint arXiv:2101.08886v3 [cs.HC], 2021, <https://doi.org/10.48550/arXiv.2101.08886>.
- [9] A. Dickinson and W. Wills, "Meals on wheels services and the food security of older people", *Health & Social Care in the Community*, 30, pp. e6699–e6707, 2022, <https://doi.org/10.1111/hsc.14092>.
- [10] C. Rudolph and S. Francis, "Making home-delivered meal programs relevant for today's aging adult.", *J Public Health (Berl.)* 30, pp. 141–150, 2022, <https://doi.org/10.1007/s10389-020-01286-z>.