Little Chef: An investigation into a private, personal cooking assistant

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ABSTRACT

With the rise of intelligent personal assistants, it is imperative that the privacy and personal security implications of these technologies helping users with daily tasks are considered. This research focuses on a private intelligent assistant to be used in the kitchen context. Little Chef (LC) has been created, an intelligent assistant which sits on a user's kitchen counter top and has the ability to speak to the user, interpret the user's comments and questions, and recognize ingredients that the user is cooking with. Furthermore, various methods (image recognition, text-to-speech, speech-to-text) are explored to create LC which bear in mind privacy by design, ensuring that the user's privacy is always protected while using the device. The study finds that such a device is possible, but with limitations.

KEYWORDS

Privacy, Speech recognition, Personal assistant, Image recognition

1 INTRODUCTION

The increase of technology as personal assistants has led to an increase in opportunities for privacy violations of individual users. Such intelligent personal assistants potentially have access to sensitive personal information about the user, such as daily habits, work location, home location, etc. In particular, personal assistants used in home contexts have access to information about when a user is at home as well as the layout of a user's home (if the assistant takes photographs), thus posing a serious security threat.

Current popular solutions on the market such as Siri and Alexa are based on an architecture which relies on sending voice recordings and usage data to the cloud for analysis in order to make these systems work [5, 18]. This presets a considerable risk to privacy as that data is vulnerable to potential misuse.

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This paper proposes an intelligent voice operated assistant in order to evaluate the question: "How can an intelligent cooking assistant incorporate privacy by design without losing its functionality for the end user". The cooking domain has been chosen in order to give this research an appropriate scope for the time available. The proposed system is called Little Chef (LC).

LC is designed to aid users with cooking skills ranging from beginner to intermediate by guiding them trough the process of cooking a recipe trough both voice and visual interfaces. In addition to providing instructions regarding the cooking procedure, LC can also execute tasks such as keeping track of progress and time, as well as making sure that the user is using the correct ingredients in the right amounts.

In order to evaluate the research question stated above, a prototype was created and used for user tests. The aim of these tests was to ensure that LC functions as an intelligent assistant with sufficient functionality and good usability. In addition, information regarding LC's use of data was provided in order to gauge the test user's outlook on the system's privacy.

2 METHODS

Concept

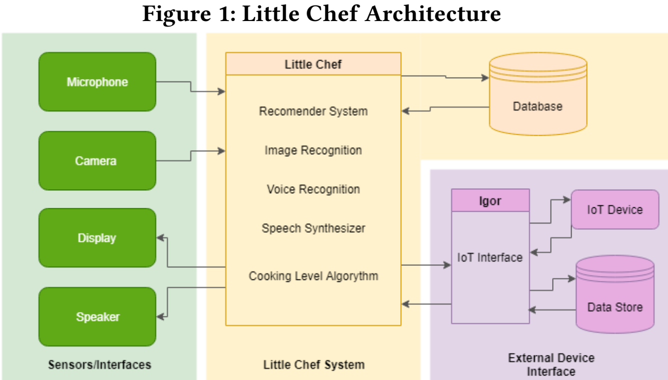
Little Chef is a private intelligent kitchen assistant which sits on the user's kitchen counter top and guides the user through recipes. LC is designed to be useful to users of all levels of skill. After just a few recipes, LC will adjust its interfaces and interaction with the user in order to provide him or her with best possible experience.

System Architecture

LC is entirely self sufficient and all of the processing as well as the data storage is done locally. LC is equipped with a microphone and a camera. These two sensors provide the inputs required by the system to function. They are connected to the main body of LC with a wired connection in order to eliminate the need for a Wi-Fi connection and therefore and potential security risks that may arise from that. The camera is positioned to see the user's kitchen countertop and all kitchen tools and ingredients the user is intending to use for the recipe.The central memory and processing unit built into the system than execute all of the tasks that LC is required to do. The system uses a speaker as well as a screen to provide feedback to the user.

LC has its own built in database where it stores recipes as well as some minimal user information such as how often each recipe has been cooked. LC also uses a predefined algorithm which takes as inputs information such as how long does the user takes per step, what level of recipes he or she chooses mostly and how often does the user cook in order to determine the user's skill level. This level is also stored in the database. The algorithm runs after each use of LC and the skill level is amended when required. Figure 1 shows a diagram of the LC architecture along with its periphery devices and connections.

Figure 1: Little Chef Architecture



Privacy Considerations

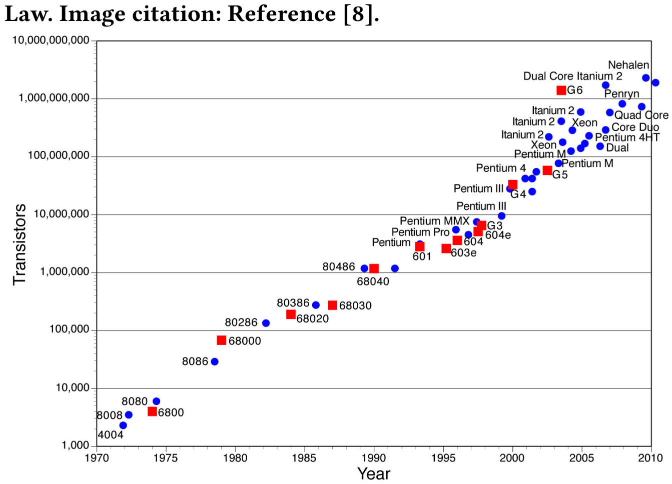
A personal cooking assistant raises major concerns regarding privacy. Namely, a camera in a user's home could capture the layout and when a user is home, posing security risks. Furthermore, data regarding which ingredients a user typically uses can allow outside entities to deduce a user's income bracket and target advertisements more effectively. Thus, in thinking about and designing LC, the users privacy is maintained by keeping in mind and accounting for the following principles:

Privacy by design. LC incorporates the privacy by design concept by following the foundational principles [9]. LC follows the principle of privacy as the default setting. All of the user data stored by LC is kept locally and never sent anywhere, hence the design decisions pertaining privacy are proactive. LC goes one step further by not having an alternate privacy setting making sure that the data stays protected. In addition all of LC's functions are able to work even when offline and self contained without a need to share any data with an external service. This means that with LC privacy is a positive-sum game [9].

Ability to run privately. LC runs privately in that all information necessary for LC to provide the user with instructions for recipes is stored on its local hard drive. This way, LC is unhosted and does not rely on a server. Additionally, the notion of zero-knowledge in privacy is taken into consideration. "[T]he traditional notion of zero-knowledge says that an adversary gains essentially 'zero additional knowledge' by accessing the mechanism" and therefore LC deletes unnecessary information from the system periodically [13]. For example, if the user requests that LC confirms whether they have the correct ingredient, LC will take an image of the ingredient and delete the image once an answer has been provided to the user.

Ability to run offline. LC runs entirely offline when conducting its main functionalities, including taking a user step-by-step through a recipe and speaking to the user. This is possible due to increasing processing power of computer chips. Specifically, Moore's Law explains a historical trend in computing power: "Moore's law states that the number of transistors on a microprocessor chip will double every two years or so – which has generally meant that the chip's performance will, too" [21]. This trend can be seen in figure 2. While the trend of Moore's Law may be "nearing its end", existing computing power for portable devices is sufficient for a portable cooking assistant [21].

Figure 2: The graph shows how transistors on a microprocessor chip double every two years, as described by Moore's Law. Image citation: Reference [8].



Thus, LC can store data such as recipes and instructional videos locally and does not need to continually refer to online sources for such information. Instead, LC comes pre-loaded with a set of recipes and instructions, and can be updated to include more recipes if the user chooses to load more recipes using a portable memory device, such as a USB stick.

Additionally, existing text-to-speech software can run offline. Namely, LC relies on PocketSphinx, "Carnegie Mellon University's open source large vocabulary, speaker-independent continuous speech recognition engine" [4, 16]. Thus, speech interactions with LC are processed within LC itself; in other words, audio clips of what the user says to LC are not sent to any online party to be processed. Speech-to-text processing takes place within LC itself, and thus the user's privacy is protected and maintained.

LC's image recognition software also runs exclusively offline. LC contains a pre-loaded image classification model which has been trained on a large dataset of food images. Image classification models are rapidly improving, especially with advances using deep convolutional neural networks for the task [17]. LC's model is trained using large existing datasets of images. One possibility would be to use the ImageNet dataset, which "is an ongoing research effort to provide researchers around the world an easily accessible image database" [1]. ImageNet is a searchable database of various images, and thus, food-related images can be used to train an effective image classification model. However, it is important to note that the model does not need to be trained on LC itself; rather, the model can be trained on an outside platform, such as Amazon Web Services, and the saved model can be loaded onto LC before the user begins interacting with LC. This way, LC does not need to store a large dataset of images (which can take up a significant portion of memory), and does not have to turn to storing these images offline.

Ability to integrate with other open systems and information services. In order to facilitate its recommendation system, LC has the ability to connect to a user's IoT enabled refrigerator to access information about what ingredients the user currently has available. It does this through Igor [2].

Igor is an "architecture for unified access to the internet of things" [2]. It is effectively a repository for data from all IoT devices around the user's home. The data is stored in XML format for homogeneity. Igor uses a REST-style interface to communicate and control the devices, which allows the system not to worry about inconsistencies in formats caused by the variety of manufacturers. This in turn means that LC can interface with any brand smart fridge. In addition, Igor is a state-based system which utilizes the DOM model of events in order to control devices [2, 15]. This can potential allow LC to interface with other smart appliances such as ovens, stoves and mixer and control them instead of the user, freeing him or her to get on with other tasks.

Finally, Igor was selected because it also conforms to important privacy principles such as running locally and hiding its data from third parties unless otherwise specified. This allows LC to gather data from third party appliances without the appliances being able to connect those data requests directly to the user [2].

Ability to move or relocate easily. Portability, to run on other devices or in other locations as a transportable personalisable service. Because LC is small enough to sit on a kitchen countertop, it can be transported to other kitchens and various other locales. Relocating LC is simply a matter of picking it up and placing it in another location. The user will ideally place LC's camera somewhere above their workstation so that LC will have a view of all working ingredients and tools, so the user would have to move this small camera to the new location as well for optimal performance.

Ambient intelligence - ability to work in a 'non-control' mode enacting decisions about and environment and /or information on behalf of owner. LC can recommend recipes to the user based on several factors. First, LC takes into account the time of day the user is requesting a recipe. For instance, if the user approaches LC around dinnertime, LC will suggest dishes usually appropriate for dinner rather than breakfast foods. Thus, while LC may have a large knowledge-base of recipes, the user is not inundated with a massive selection at each use. Second, LC stores information about how many times a user makes a specific recipe. Because LC has data about each recipe (ingredients, time to prepare, etc.), LC can use this information to recommend similar dishes or the same dish. Third, the user is prompted for a rating of the recipe once making a dish, and this rating can be taken into account when recommending new dishes. This method of asking for user ratings has been employed previously by researchers developing a personalized recipe recommendation system [11].

In order to ensure that the recommender system will provide the user with recipe recommendations in a completely private manner, LC is pre-loaded with a knowledge-base. This knowledge-base consists of a food ontology, health based dietary rules, the recommend engine, and the user's interaction with LC [19]. This knowledge-base framework was modified to incorporate LC and can be seen in figure 3. The 'Web User Interface' was replaced with the offline LC interface to ensure that no unnecessary web-based connections are made. By doing so, the potential risk of exposing private user data is minimized. The knowledge-base enables LC to make recommendation without knowing any personal data in advance [19] and thus establishes functionality for the user by incorporating privacy by design.

The food ontology is subdivided into 13 distinctive food categories including egg products, grain products, nuts and seeds, seafood, meat, etc. Where the nutrients of each category are defined by 50 properties [7]. By using this ontology

Figure 3: The adaptation of the knowledge-base framework Image citation: Reference [19].

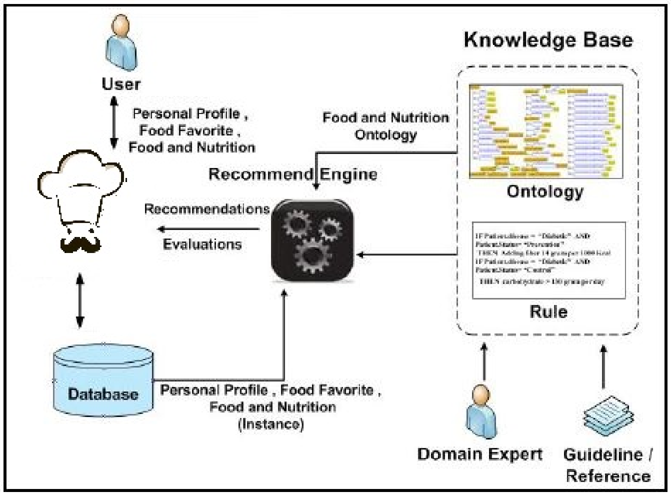
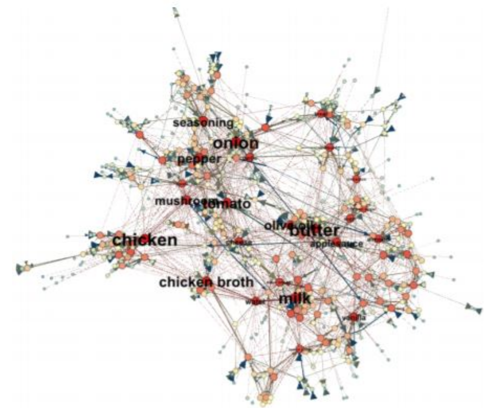


Figure 4: The figure shows the ingredient substitute network found by analyzing 46,337 recipes and 1,976,920 reviews. Image citation: Reference [20].



the nutritional value of each ingredient used in the recipes of LC can be defined. If a user is willing to provide LC with their height and weight, which will subsequently be stored offline in LC's database, additional functionalities can be unlocked. By using a 'health improvement' opt-in function, the user will be provided with recommendations based on the nutrients that they consumed from previous recipes that were made with LC. These healthy recommendations strive to fill any nutritional gaps in the user's diet [12]. For instance if: 'User X's favorite food is chicken and has a BMI (Body Mass Index) = 27', LC can recommend a low-calorie diet with oven-baked chicken breast as its main ingredient.

Moreover, if LC is connected to a smart fridge, it can use the abilities of Igor to provide the recommend engine with the available ingredients the user has to its disposal [2]. This recommend engine will then combine the user preferences with these ingredients and search in a ingredient network for potential recipes. By using a network of ingredients, LC will not only statically look for recipes with the available ingredients, but can incorporate substitute ingredients to improve the recommendation considerably [20]. Figure 4 shows a ingredient substitute network found by analyzing 46,337 recipes and 1,976,920 reviews.

LC will continually update the recommender system when new data is added (i.e., when a user cooks another recipe). The recommender system will ultimately use a machine learning method to predict what score the user will give to any given recipe. For instance, the recommender system could rely on a simple linear regression model which takes into account the aforementioned variables or a subset of these (for instance, how many times in the past the user has made recipes with the same main ingredient, the time of day, the number of times a user has made a similar recipe).

Prototype Implementation

User Interface. Various screens for LC were prototyped. When the user first turns on LC, they will be greeted with a few recipes that LC thinks the user will enjoy, as seen in figure 5. The welcome screen features a personal greeting at the bottom (in this case, "Hi Tim." The user has the option to enter their first name when first starting LC, and LC remembers the the name for future use to create a familiar experience for the user. Additionally, the user can swipe through a few pages of recipes (as indicated by the small circles near the top of the screen) to browse other options. Upon swiping to the final page of recipe suggestions, the user will have the option to search for a recipe of their choice. The navigation between pages can also be executed by giving LC a "Show me more" voice command for next page and "Back" voice command to return to previous page. LC can also filter recipes by category, alphabetically or by skill level required. This feature is accessible via the voice interface. As the system is designed to be voice operated, the interface does not include any buttons. This trend continues throughout the prototype.

Once the user selects a recipe, by either using a voice command (for example, "Little Chef, I want to make guacamole.") or tapping a recipe image, they will be directed to a screen similar to figure 6. On this page, the user sees the title of the recipe as well as timers for the recipe. These timers are especially useful for recipes which involve multiple concurrent tasks, for instance, keeping something in the oven for 30 minutes while pan-frying vegetables. Additionally, the user sees the current step in the recipe at the bottom of the screen. While the same instruction has been verbally communicated

Figure 5: This screen shows the user several recipes that LC thinks the user will enjoy.

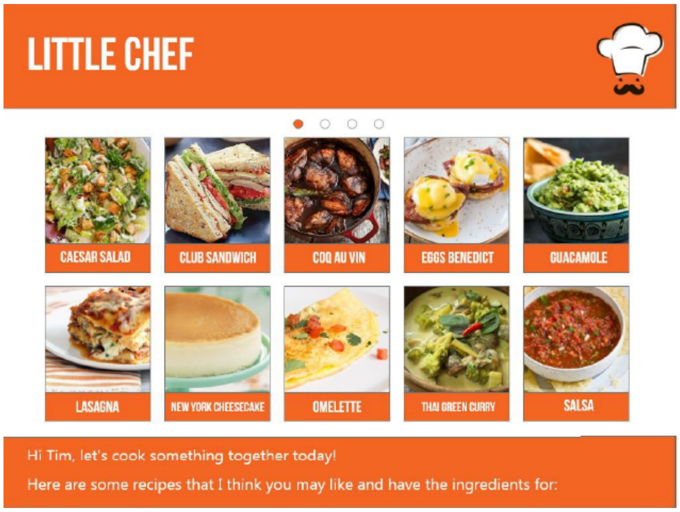
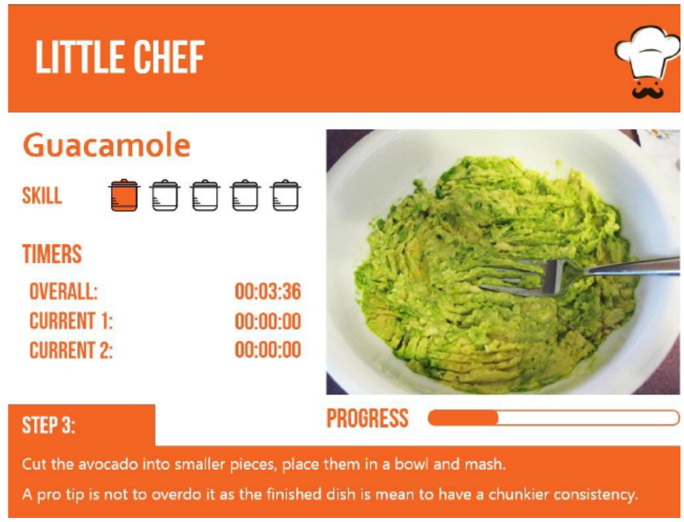


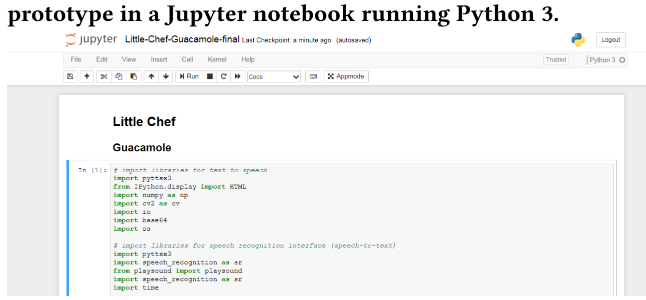
Figure 6: The recipe page includes the current step the user is on, a place where the user can view instructional videos, and recipe timers.



to the user by LC, the written instructions serves as a reference for the user. The final portion of the recipe screen includes an video box inlay and progress bar. The video box shows the user instructional videos as needed. In this particular instance, the video box is showing the user how to mash an avocado. The progress bar below the video box indicates how far in the recipe the user is currently. Furthermore, the interface includes a subtitle like text displaying the current command as a kitchen can often be quite noisy and therefore the user may not quite hear an instruction. In that scenario the user may also use a "Repeat" voice command in order to prompt LC to repeat the last thing it said.

Interactive Guacamole Tutorial. The interactive prototype of LC was coded in Python 3 and runs on a Jupyter notebook on a laptop with a speaker, microphone, and webcam. A screenshot of the Jupyter notebook can be seen in figure 7. The prototype begins by speaking to the user ("Hi! I'm Little Chef, and today I am going to show you how to make guacamole."), and takes the user step-by-step through a recipe for guacamole. (Due to time and resource constraints, the visual user interface could not be integrated with the interactive tutorial.) Little Chef continues giving audio instructions to the user, pausing every so often to allow the user to complete tasks and check in with the user to see if they are ready to proceed ("First you will need one avocado. When you have your avocado, say yes after the beep."). The user can ask LC to repeat instructions or wait for a while when LC asks what it should do ("'I do not understand. Do you want me to wait, repeat the ingredients, or continue?"). Additionally, LC checks whether the user indeed has an avocado at the start of the recipe by asking the user to hold up an avocado to the camera for LC to see.

Figure 7: A screenshot of the interactive component of the prototype in a Jupyter notebook running Python 3.



To enable LC to speak to the user, pyttsx was employed, a Python library which enables "[o]ffline text to speech" capabilities [6]. Because the software runs offline, no text needs to be sent to an outside source, maintaining privacy. On the hardware side, external speakers were not needed because the LC prototype was run on laptops with built-in speakers.

Implementing speech-to-text capabilities was the more involved, challenging task. The SpeechRecognition library for Python 3 was used, which came with various softwares for speech recognition [3]. These softwares include Google Audio and Pocket Sphinx. LC first used Pocket Sphinx due to its ability to run offline and therefore protect the user's privacy. This later switched to Google Audio instead due to Pocket Sphinx's inability to understand simple phrases even though Google Audio does not run offline. This change was necessary to test the usability and value of LC (discussed in Results). Most of the laptops had built-in microphones which could capture user speech, however for one laptop which did not have a built-in microphone, an external USB microphone was used.

Each time LC takes a picture of what the user is holding up, LC overwrites the previous picture taken. This way, LC does not accumulate a vast store of user images. Additionally, the pre-trained model needs to be loaded once from the internet and can run without internet connection, an important consideration for reducing security risks. (For the full-fledged version of LC, this model would be pre-loaded for the user so they do not have to connect to the internet to download the model.)

User Testing

Two rounds of user testing have been conducted with three participants for each. The following section gives a detailed description of the test setting, procedure and evaluation procedure.

Participants. Six participants in total were selected for this study. The sample population was chosen on the basis of the criteria shown in table 1.

Table 1: Test user criteria and justification

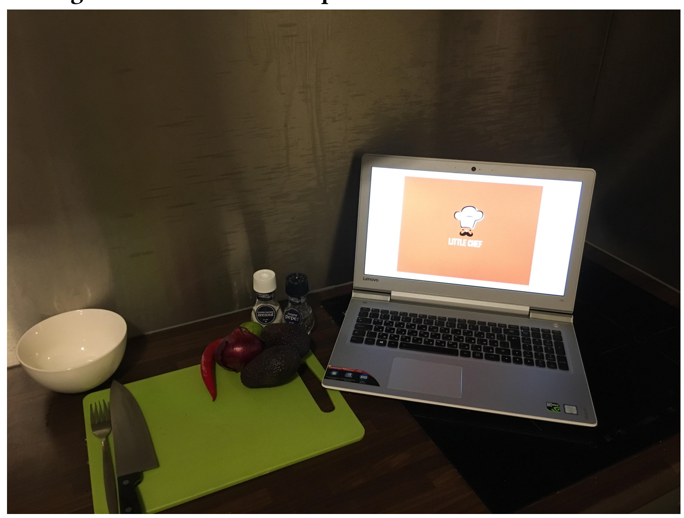
Criteria	Justification
Age Bracket: 18 - 60	The age bracket for test has been set quite high as LC is designed to be used by users of all ages.
A mix of cooking skills	LC should be useful by users of all levels of cooking ability. Each group should be represented by at least one test participant
Not much experience with voice assistants	In order to truly gauge the ease of use of LC, it is important to conduct the test with users who do not have much experience with voice operated intelligent assistants. An assumption can be made that if inexperienced users perform well so will experienced ones.

Table 2 shows the information of all the participants gathered with the pre-test questionnaire.

Table 2: Test user information

Participant	Age	Cooking Skill Level	Experience with a Intelligent Assistant
1	25	Advanced	No
2	19	Advanced	No
3	27	Advanced	No
4	54	Intermediate	No
5	21	Intermediate	No
6	27	Beginner	No

Figure 8: The initial set up used for one of the tests.



Setting. Each of the tests was conducted in a kitchen with enough space so that the test participant could be provided with a cutting board, bowl, fork, kitchen knife, all of the ingredients required for the recipe, and a laptop running the Little Chef prototype. An example test setting can be seen in figure 8. A moderator and an assistant were also present.

Task. The test participants are asked to make a guacamole by interacting with LC. The prototype then guides them through the process by providing information about each step. The prototype also verifies the user's ingredients and progress at one step each in order to test the functionality and the user's opinion of the feature. In order to complete the task the test participant has to interact with LC through its voice interface.

Evaluation Procedure. When conducting the usability tests, a standardized procedure was followed to ensure the constancy and more importantly comparability of the results. The steps taken in the test procedure are:

1. Test participant is welcomed and given a short explanation of the proceedings as well as information about the test environment.
2. Consent form is given to the test participant to sign.
3. Pre-Test questionnaire is given to the test participant to complete.
4. Test participant is given the task and asked to complete it in his or hers own time
5. Test participant is given a post-test questionnaire.
6. An unstructured interview is conducted with the test participant.
7. Test participant is thanked and dismissed.

Intended Outcomes. During the first round of user testing the core functionality and operation of the prototype is expected to be the focus of the results. In other words, where did the user spent too much time, did they get stuck and did they participate naturally in the dialog with LC? In the second round the effectiveness of the improvements from the first round was examined and a stronger emphasis was placed on privacy.

3 RESULTS

The first and second user test gave valuable results as to what improvements can be made to the LC prototype. The full results, the pre-test and post-test questionnaire, can be found in appendix A and B. The first user test gave the following insights:

Users had problems with speech recognition. The speech recognition system Pocket Sphinx would often not understand the users. As a consequence, the user was unable to proceed cooking, since LC did not understand if the user was done with a step. This issue was solved by changing Pocket Sphinx to Google Audio. Using Google Audio could raise privacy concerns. However, it was implemented for the purpose of testing the prototype. This change allowed for easier conversation between LC and the user.

The speech interface was too fast for the users. LC was not allowing users enough time to finish a step of the recipe before asking "Have you finished this step?". Consequently, LC repeated itself too much by asking the same question repetitively in a short time span. This was a point of frustration with all users. As a result, the times LC allowed to perform steps of the recipe were changed.

LC was unable to recognize ingredients properly. The LC prototype uses a pre-trained image recognition model, which could not recognize avocados appropriately. As a solution, a different recommender system based on the ImageNet dataset could be build. This dataset is greater than the one used for the current image recommender system of the prototype and therefore might improve results.

The second user test led to the following results:

LC's waiting time per step should be dependent on the skill level of the user. During the first test, all testers described themselves as advanced chefs. However, the second test was conducted with users of lower skill levels as well. This showed that while some users could perform a step of the recipe within the allocated time (until LC asks if they wish to continue to the next step), other users would be far from finished. The user experience of LC will be improved if the skill level of the user is taken into account in the calculation of the waiting time per step.

Users do not want LC to be listening for "Hey Little Chef" constantly. The user can either say "Hey Little Chef" to start LC or click on it's screen. The test users expressed concerns about a device listening continually in their homes. To resolve this concerns, LC can have a setting were the microphone will be turned off after finishing a recipe. The user will then have to click on LC's screen when they would like to cook again.

Users prefer a personal assistant to have privacy and quality over speed. When having to choose two of these three characteristics, speed proved to be the least important. Users would rather maintain their privacy by not having their data shared. Furthermore, they prefer all requests and responses of the personal assistant to be highly accurate. Having quick interaction with the personal assistant fast processing was the least preferred characteristic. Furthermore, it was observed that although users prefer privacy, most have not exercised their GDPR rights.

Users find it unacceptable that Little Chef stores images internally. When first asked if the users minded LC storing images internally, most users responded that they do not mind. However, the questionnaire then posed the question "did you consider that Little Chef would take pictures of your environment?". The users who did not mind LC storing images responded no to this question. After this the first question was repeated to see if the users would change their minds when introduced to privacy concerns. Indeed, all users now indicated that they do mind if LC stores images internally.

Users do not mind if LC stores data such that it can give them recommendations. All users found it acceptable that LC stores personal prior acquired data in order to give them good recommendations. A few different reasons were given for this acceptance. First, users would like to be recommended recipes they do not know yet, but quite possibly will like. Second, they would find accurate recommendations, achieved by storing personal data, more helpful. Third, they do not see the data LC would store as personal data.

4 DISCUSSION

With the rise of personal intelligent assistants such as Siri, Alexa, and Cortana, some of us envision that AI is there to improve our daily lives, and that is obviously the case. End users which had the chance to experience the added value of a private intelligent assistant, albeit to a limited degree due to it's stage of infancy, are seeing the added value. Nonetheless, questions related to privacy are being pushed into the back and pale in comparison to the features AI promises and delivers. The euphoria related to AI, makes us forget the importance of privacy, and if AI is at it‘s infancy, privacy in context with personal assistants does not exist, yet. Hence, this research focused on whether it is possible to build a working private intelligent assistant which incorporates the concept of privacy by design with the help of open source packages and whether it added value to the users.

The research was conducted by simulating a scenario of how an assistant could perform in a given domain setting (for this research cooking with LC), and by stimulating the end users to perform accordingly. Aspects pertaining the interaction of "assistant to user" as well as actual reflections of our users, while focusing on privacy, were observed. It was identified that none of the users had prior experience with personal assistants, which was an unique chance to observe "first-time" users. This observation also led to the believe that the current market related to personal assistants is immature and leaves a lot of room for growth.

During the usability test, domain specific issues appeared which should be noted. They were either in regards to technical limitations and time, for example speech and image recognition not working with high accuracy, or in regards to user interface related shortcomings, such as the voice interaction not being polished. Nonetheless, none of these affected the privacy component, and in fact privacy measures were the sole reason users experienced those difficulties. The reason for those difficulties are related to the choice of open source packages. By moving for example from PocketSphinx (High privacy, low quality, but offline) to Google Speech (High quality, low privacy, but online), immediate improvements in the interaction were observed, but at the same time privacy by design was neglected, hence the research team wants to point out that it is possible and feasible to create a working speech interface with privacy by design doctrines, but for the sake of the experiment and this research, Google Speech was utilized to decrease user frustration. Similar trends were also observed with ImageNet.

Trading off between packages and aiming for a standard in privacy for LC showed that there is a paradigm: Developing and incorporating privacy by design comes with trade-offs. Privacy and speed or privacy and quality, both are feasible, but having all three distinct aspects incorporated into one personal assistant (namely: privacy, speed, and quality), requires further resources, i.e. human cost and time. The recognized trend of the end users preferences was that privacy and quality are the preferred characteristics. Speed was negligible. This led to the next question of how "aware" users were when exposed to privacy related aspects, given their preferences.

During the user test, some users did not mind that their images were saved, however changed their mind once they got informed that the assistant might perceive their immediate environment (kitchen/living room). This showed that users do care about privacy when they are informed, and that can raise further questions as to what the implications would be, if users were made aware of the consequences when using personal intelligent assistants. One possible solution could be to work on a permission oriented approach (opt-in) to enable features, by explicitly informing the user whenever sensitive data is being captured and processed.

Further, users do seem to not mind that a personal assistant would store prior known data for the purposes of a recommendation systems. This observation adds a caveat to the process of when is it acceptable to store data and when not. Some responses of the users ranged from not thinking the data is sensitive enough, or they were willing to accept the trade off between exposing habits for the purpose of new recipes. Moreover, the interviewed users are situated in the EU, but most had so far not interacted with the GDPR rights they own, hinting that they did not take the chance yet to ascertain their data stored by third parties. Given these observations, this raises additional questions in regards towards sensitivity of a user's privacy and their willingness to give data up.

Additional observations were made that users overall were ready to accept temporary exposure of privacy for the purpose of interaction (e.g. assistant listening in during the whole cooking process), however with the caveat that there should be a "mechanism of control", where the user knows when he is listened to. This showed the team that if there would be a polished private personal assistant which includes all aspects pertaining privacy, control mechanisms will be of importance to the user.

This research finds that privacy by design incorporated into a personal private intelligent assistant is a possible and feasible endeavor, furthermore it was seen that there are features which can allow for satisfactory user interaction. However, satisfactory is a big variable. Users had exhibited behavior which showed that their awareness of data is limited, but they do prefer various features. Therein lies a challenge for developers in the future, to provide a sensible solution which appeases to the users privacy requirements and demands. It however is imperative that users should be made aware of the implications of using the assistants. They might be euphoric to have the features they wish, but at the same time they might lose their privacy.

Future Research

Onion Routing. The initial design proposes a system that is completely offline in order to provide maximum privacy for the user. However, in order for the LC to truly be competitive with main stream services currently on the market it should be able to access resources on the world wide web as and if required. In order to maintain the user's privacy and withhold his or her personal identity even when accessing third party services several obfuscation techniques should be examine.

One such possible solution is to utilize onion routing. [14] This refers to accessing an internet service provider to a series of intermediary servers. Since the messages have a multilayered encryption each of which can be decrypted only by one of the servers, the identity of the user making the requests remains concealed. This in turn prevent the third party of connecting this request to a specific user, building a profile and targeting that user with advertisements and other specific messages.

Privacy Concerns. Concerns were raised during the research regarding the privacy awareness of the users and their willingness to give up their privacy for perceived added value from a private intelligent assistant. The bigger picture was not perceived, but users were opting for privacy when the concerns were raised. Hence, further research can be conducted to gauge the willingness for trade offs between privacy and features, when users are properly informed. Moreover, various methods to introduce and properly inform users of the privacy implications could also be investigated.

Ingredient Amount Recognition. While the feature of recognizing amounts of ingredients through the camera sensor is discussed it is never actually implemented. The research by Eppel and Kochman [10] presents a good start in tackling the problem as they present a method to recognize volumes of liquids using computer vision. However, their solution has only been tested on liquids placed in clear containers. Therefore, further research will be required.

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A PRE-TEST QUESTIONNAIRE

What is your age (in years)?

1: 25; 2: 19; 3: 27; 4: 54; 5: 21; 6: 27

Do you have an interest in learning new cooking skills?

1: Yes; 2: Yes; 3: Yes; 4: Yes; 5: Yes; 6: No

Do you use an intelligent personal assistant on a regular basis?

1: No; 2: No; 3: No; 4: No; 5: No; 6: No

If yes, how often do you use the assistant? - Daily - Weekly - Monthly - Other:

Please describe how you use the intelligent personal assistant:

What is your skill level as a chef?

1: Advanced; 2: Advanced; 3: Advanced; 4: Intermediate; 5: Intermediate; 6: Beginner

How often do you cook?

1: Daily; 2: Daily; 3: Daily; 4: A few times per week; 5: Daily; 6: A few times per week

B POST-TEST QUESTIONNAIRE

Which aspects did you like most about Little Chef?

1: The fun of failure; 2: It helped me make guacamole; 3: I like it talking cause it's a nice company; 4: Hearing the steps instead of having to read, so I can continue cooking and it's handy when your hands are dirty from cooking; 5: Good order of instructions, which helps you stay organized while cooking. Informative part, in other words the extra information such as why you need lime in the recipe.; 6: The pictures made me feel sure I was doing the right thing.

Which aspects did you like least about Little Chef?

1: That it didn't recognise yes all the time; 2: It did not understand my voice and I had to repeat myself several times, which was frustrating; 3: that it does not allow for a breather in between steps; 4: How hurried it was; 5: Too fast at times, and too slow at others (calibration of microphone); 6: It did not wait for me, not complete - did not tell me to mix the ingredients, it assumed I knew how to cook - I did not know how to cut avocado and onion - wish it had more info for me as a beginner.

Did you get stuck anywhere in the cooking process?

1: No, but went too fast; 2: Yes, almost all the times I had to speak, it did not understand me; 3: Yes; 4: Yes; 5: No; 6: Yes, when cutting the onion

Did you experience any of the following issues? (more than one may apply)

a. Little Chef did not understand me when I was speaking

b. Little Chef did not recognize my ingredient when it was, in fact, the right ingredient

c. Little Chef's questions to me were unclear

d. Little Chef's instructions to me were unclear (sometimes)

e. Little Chef did not provide enough detail in instructions

f. Little Chef provided too much detail in instructions

g. Other:

1: a,b,d; 2: a,b; 3: a,b,d,e; 4: b; 5: a,b; 6: b,e

Imagine Little Chef could help you with a wide variety of recipes. Which features would be valuable to you? (more than one may apply)

a. Product/ingredient recognition

b. Voice recognition

c. Video tutorials

d. Progress trackers

e. Progress timers

f. Ability to speak to Little Chef

1: c,e; 2: a,b,c; 3: b,c,d,e,f; 4: b,c,d,f; 5: c,d,e; 6: a,c,d,e

Have you used any other products that achieve the same outcome as Little Chef? If Yes, which ones?

1: Yes, Written recipes and own experimenting; 2: No I have not; 3: No; 4: No; 5: No; 6: No

How much effort did it take to cook with Little Chef?

a. More than usual

b. Usual

c. Less than usual

1: a; 2: a; 3: a; 4: b; 5: a; 6: c

Would you recommend Little Chef to a friend?

a. Yes, why:

b. No, why:

1: b. Bad communication with the machine and it takes too long; 2: b. It did not understand my voice and I had to repeat myself on several occasions, this meant that it took an unnecessary time to make, would not use again; 3: b. It needs further development; 4: b. It did not make cooking easier, since the waiting time was too short; 5: a. I have lots of friends that want to learn to cook but can't and this would be useful; 6: a. It is funny and somehow a unique experience

When exposed to personal assistants such as Alexa, Cortana, Little Chef, or Siri, what would be your first concern?

4: If the microphone will be turned off after using it; 5: Camera and microphone deactivated; 6: Privacy

Consider that Little Chef has given you a recommendation, based on your personal prior acquired data, would you mind that Little Chef stores data ?

a. Yes, why:

b. No, why:

4: b. I would like to have good recommendations, would like to learn new recipes I will probably like; 5: b. I don't see the information that Little Chef has as intimate; 6: b. If the recommendation is accurate I would find it helpful

Voice activation, via trigger-words such as "Hey Siri", or "Hey Little Chef" are invaluable for a hands-free experience, but have to be listening to the environment. Would you be ready to disable this functionality, in order for the assistant to not listen to your environment?

a. Yes, why:

b. No, why:

4: a. For privacy reasons; 5: a. Privacy; 6: a. Privacy

Little Chef has shown you some functionalities, such as taking pictures to recognize ingredients. Would it be acceptable for you that Little Chef stores those images internally?

4: No; 5: Yes; 6: Yes

In regards to the previous question "Would it be acceptable for you that Little Chef stores images internally?", did you consider that "Little Chef" would take pictures of your environment? (e.g. identify what your home looks like, imagine it sees a TV in the background, your private collections etc?)

4: Yes; 5: No; 6: No

Does your answer to the question "Would it be acceptable for you that Little Chef stores images internally?" deviate from the first time we asked you this question?

a. Yes, why:

b. No, why:

4: b. I had already considered it a bit; 5: a. I did not consider it; 6: a. Didn't think about it.

Considering you care about your personal assistant, which of the following characteristics do you want your assistant to have? (Only two can be selected)

a. Speed (quick in interaction with your requests processing)

b. Privacy (your data will not be shared)

c. Quality (all requests and responses will be highly accurate)

4: b,c; 5: b,c; 6: b,c

Have you ever looked into GDPR, and requested data or data deletion on your behalf or someone else's?

4: No; 5: No; 6: Yes