A Demonstration of cARe: An Augmented Reality Support System for Geriatric Inpatients with Mild Cognitive Impairment

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Figure 1: Locations for in-situ instructions are positioned in the room via gaze pointer (i.e., the current location to be positioned is following the current gaze direction) and AirTap gesture (a). This way, virtual locations can be attached to their real-world counterpart (b) to present instructions at their corresponding position (c).

ABSTRACT

Cognitive impairment such as memory loss, an impaired executive function and decreasing motivation can gradually undermine instrumental activities of daily living (IADL). With an older growing population, previous works have explored assistive technologies (ATs) to automate repetitive components of therapy and thereby increase patients' autonomy and reduce dependence on carers. While most ATs were built around screens and projection-based augmented reality (AR), the potential of head-mounted displays (HMDs) for therapeutic assistance is still under-explored. In this interactive demonstration, we present *cARe*, an HMD-based AR framework that uses in-situ instructions and a guidance mechanism to assist patients with manual tasks. In a case study with six geriatric patients, we investigated the prototype's feasibility during a cooking task in comparison to a regular paper-based recipe. Qualitative and quantitative results indicate that *cARe* has potential to offer assistance to older individuals with declining cognitive function in their day-to-day tasks and increase their independence in an enjoyable way.

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CCS CONCEPTS

• **Human-centered computing** → **Accessibility technologies**; *Mixed / augmented reality*; • **Applied computing** → Computer-assisted instruction.

KEYWORDS

assistive technology, dementia, augmented reality, mixed reality, IADL, in-situ

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1 INTRODUCTION

As to this day, dementia is a not fully explored condition that affected about 47 million people worldwide in 2015 and is expected to reach 75 millions by 2030 [21]. With a worldwide lack of caregivers, researchers are looking for ways to alleviate the burden on both, patients and caregivers via interventions [3] and assistive technologies [19]. This way, the independence of patients can be increased while the immense treatment costs for dementia can be reduced [22].

With the development of stand-alone AR HMDs such as the Microsoft Hololens, AR became a promising platform for assistive technology [19]. AR support of manual tasks such as maintenance [8], assembly [1] or surgery [6] has been widely researched over the course of the last five decades. These setups usually consist of four key features: registration of objects and spaces via maker-based or marker-less tracking [1], object-fixed or world-fixed virtual content [17], step-by-step instructions [12], and guidance between points of interest [4]. With the development of the inside-out-tracking approach, AR applications for HMDs have found their way into non-instrumented environments such as private homes. The ability to augment every-day objects with visual and acoustic information opened a new path to assist occupational therapists and geriatric patients. However, while related work focused on target groups such as surgeons and industrial workers, usability requirements for cognitively impaired users are still being explored [14].

As a contribution to this effort, we developed a generic AR framework that can be set up by caregivers without any programming knowledge to assist patients with cognitive impairment such as dementia in various manual tasks. The framework's architecture allows it to support any sequence of manual tasks to be a flexible tool for both patients and caregivers. While the framework could theoretically support many tasks, cooking is one of the first IADLs that is affected by dementia and was therefore chosen as an example use-case for the case study [5, 20]. While preparing meals has been the focus of previous work targeting cognitively impaired individuals, to our best knowledge this is the first HMD-based approach [2, 16].

This work presents the prototype by Wolf et al. [23].

2 *CARE* CONCEPT

The ability to perform tasks of daily living independently is a key aspect of an individual's quality of life [20]. Especially older people and patients with cognitive impairment are at risk of functional loss and require regular therapy to retain their independence. With a growing older population and a lack of personnel, caregivers will not be able to provide the same quality and quantity of therapy in the future [13, 18]. To alleviate the burden on caregivers and patients, we propose to outsource repetitive components of therapy sessions to assistive technology. Our vision is that a sophisticated AR system can lead patients through their day-to-day tasks in a caring way while giving them the feeling of independence. The system could be extended by real-time support from therapists or relatives to guide patients through potentially critical tasks such as sorting their pills for the week by providing visual cues in their field-of-view without giving them a feeling of "surveillance" [9]. To test the feasibility of this concept the *cARe* framework was implemented with a user-centered design approach that included repeated pilot studies with cognitively impaired patients and discussions with their caregivers to meet the requirements of both user groups. During discussions, caregivers acted as intermediators as proposed by Johansson et al. [10]. The insights gained during pilot tests and the final framework consisting of a caregiver and a patient application are described in the following.

2.1 Caregiver Application

The input required by caregivers to set up *cARe* for a patient can be seen as two steps: Content generation and room set-up.

2.1.1 Content Generation. Instructions for cognitively impaired patients are in general more detailed than those for users without cognitive impairment (e.g. due to limited memory retention) meaning that a simple cooking recipe can result in many individual instructions, e.g. 'Take a spoon from the drawer'. To facilitate the creation of these instructions a recipe editor was implemented in Windows Presentation Foundation (WPF) with a graphical user interface. Creating a new set of instructions from a given recipe consists of the following steps: First, key-locations required for the recipe are defined, e.g. 'fridge', 'drawer' and 'stove'. Then, individual instructions are created and each is assigned to its key-location, e.g. 'Take a spoon from the drawer' to 'drawer'. Pilot tests revealed that complex instructions that include the usage of a scale or measuring cup require additional assistance. To this end, each instruction can be assigned an image file to clarify complex tasks such as using a specific tool or to present a picture of the desired result (see Figure 1 c). Finally, the instructions are exported as an XML-file and copied to the HMD. This step has to be completed only once for each new recipe and concludes the content generation process.

2.1.2 Room Set-Up. Having completed the content generation and, thus, copied the instructions to the HMD, caregivers can now set up a new room for *cARe* support by assigning all key-locations from the list of instructions to their real-world positions. To this end, a Hololens application written in Unity3D displays a mesh of the environment and visualizes the intersection point of the user's current gaze direction with the mesh. Using the Hololens AirTap gesture, key-locations can be positioned in the room (see Figure 1 a). The application iterates over all key-locations until each has been assigned to a position (see Figure 1 b). Key-locations can be re-positioned using the same technique, namely gaze-cursor for pointing and AirTap for selection. Depending on the current recipe, the room set-up takes only a few seconds to complete and could be also performed by caregivers and relatives in the user's home in the future.

2.2 Patient Application

In consideration of the specific requirements of cognitively impaired patients reported by related work and experts interviewed during the development of this framework, several mechanisms were integrated into the patient application that was written in Unity3D: an intuitive guidance mechanism, a natural interaction concept, and a motivation mechanism to encourage patients.

2.2.1 Guidance. To provide location information and reduce mental load on the patients, *cARe* uses in-situ instructions, i.e. instructions are displayed at the location they should be executed at. To assist patients in discovering these locations a guidance mechanism was developed in an iterative process. Depending on the kitchen floor plan key-locations can be far from each other or on opposite sides of the room which is challenging considering that the field-fo-view (FoV) of the Hololens is limited to 30°. Pilot tests of spatial audio cues against visual cues resulted in lower error rates for the visual cues which is consistent with related work [11]. To prevent the visual cue from intersecting with the patient its shape is defined as a Bezier-curve around the patient and updated dynamically (see Figure 2). The curve is calculated via a quadratic Bezier-function that is described by the points P_0, P_1 and P_2:

$$\mathbf{B}(t) = (1 - t)[(1 - t)\mathbf{P}_0 + t\mathbf{P}_1] + t[(1 - t)\mathbf{P}_1 + t\mathbf{P}_2]\ , 0 \le t \le 1 \quad (1)$$

In early prototypes the cue was drawn statically between two consecutive instructions which occasionally resulted in patients losing sight of the cue due to the small FoV. Recovering from this situation proved as challenging since patients were not familiar with the concept of a FoV. For the final prototype, the cue was re-designed to start at the patients' center-of-view and end at the new instruction position (see Figure 3 a-b). The cue is hidden as soon as the gaze cursor enters the next instruction (see Figure 3 c) and reappears if the patient finishes the current instruction, asks for help or is idle for too long (see Figure 3 d).

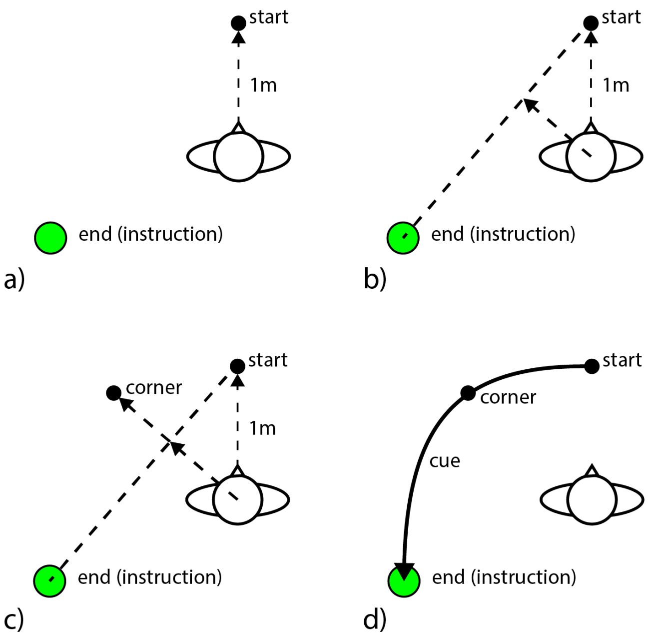

Figure 2: Guidance cues update their shape dynamically. The quadratic Bezier-function used to draw the shape expects three positions: a starting point, a corner point, and an end-point. In each frame, the starting point is defined as a position one meter in front of the patient's current gaze direction and the end point as the current instruction position (a). To determine a corner point that will curve the shape away from the patient, the HMD's position is first projected on the vector between start and end point (b). The normalized vector between HMD and the projected point is multiplied by a pre-set factor and added to the projected point (c). The resulting corner point can now be used to calculate a Bezier-curve (d).

2.2.2 Interaction. A low mental demand for the interaction concept was imperative due to the patients' cognitive impairment. Learning from related work, the interaction via gaze cursor and gestures is physically and mentally too demanding for cognitively impaired patients. Thus, voice input was chosen as the most intuitive and natural interaction modality. Designing an audio interface

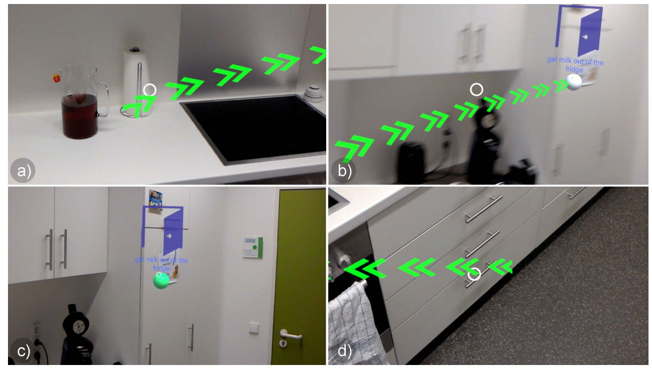

Figure 3: Patient's view of the system: When a new instruction is displayed, patients are guided via cues from their current center-of-view (a) towards the new instruction (b) until the gaze pointer enters the next instruction (c). Saying 'help' or staying idle for a certain amount of time will trigger a cue from the current center-of-view towards the current instruction (d).

for cognitively impaired patients is challenging. First, the set of commands has to be kept low due to limited memory retention and be intuitive so that commands can be recalled by logic and instructions repeated if necessary [7]. Second, many cognitive impaired patients suffer from depression and reduced motivation meaning that speech recognition and response time has to be optimized to prevent frustration and confusion. With these requirements in mind, a small set of commands was defined in collaboration with patients and caregivers and validated in several pilot tests:

- **'start':** Initiates *cARe* assistance (if the room has been set up beforehand).
- **'next':** Displays the next instruction and draws guidance cues from the current center-of-view. A timeout mechanism prevents triggering this command twice in a row.
- **'back':** Displays the previous instruction and guides towards it.
- **'help':** Draws guidance cues towards the current instruction (if it has been found previously).

The 'back' command was added after some patients ended up skipping instructions while talking to themselves and accidentally saying 'next' in the pilot tests. To prevent frustration during the experiment, a WPF application was implemented as a wizard of Oz mechanism. This way the patient application can be controlled remotely in the case that the speech recognition fails to recognize a command.

2.2.3 Patient Motivation. As cognitively impaired patients often suffer from a feeling of insecurity and a low self-esteem, e.g. due to depression, they require additional motivation. During pilot tests, some patients stopped mid-task and needed additional assistance to continue. In a regular patient-caregiver cooking session caregivers provide regular praise and encourage patients to continue should they get frustrated or get lost in thoughts. Since natural voices are preferred by older adults, this behavior was integrated into the *cARe* framework by recording voice samples of the patients' caregiver containing praising phrases and encouraging words [15]. These voice samples are played back after each completed instruction when the patient triggers the 'next' command. Should patients stay idle for too long, an encouraging phrase is played back to remind them of their task and a visual cue guides them back to the current instruction.

3 CONCLUSION

We have presented *cARe*, an AR framework that can support caregivers in treatment of cognitively impaired patients by outsourcing task support and training for IADLs to an AR assistive system. The prototype was carefully designed in collaboration with experts, caregivers, and patients to meet all the necessary requirements for a support system that allows cognitively impaired patients to retain the ability to perform IADLs autonomously. In an iterative approach, we implemented and evaluated a novel guidance mechanism, a voice interface, and a motivation mechanism. Patients were generally positive towards the new technology and were successful in cooking with *cARe* support. From a geriatric point of view this case study clearly demonstrates that augmented reality may support those everyday functions that got lost in older persons with missing day-to-day practice, experience, or due to aging and disease.

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