HomeModAR: A Home Intervention Augmented Reality Tool for Occupational Therapists

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ABSTRACT
This paper reports on the exploration of a tablet-based augmented reality (AR) application for use by occupational therapists (OTs). The application enables OTs to support individuals with *physical impairment and disability* when making home modifications. This is a necessary process that empowers these individuals to compensate for their reduced abilities and to maintain independent living. Through semi-structured interviews and a participatory workshop, current home modifications and the challenges involved in the process of implementation were investigated, and an AR prototype was co-designed with the OTs. They found the AR tool to be potentially beneficial as it allows them to search, find, and select assistive technologies (ATs) for use in homes and to demonstrate the home-modification plans to users. The tool will enable users to envision the most appropriate scenarios when purchasing and utilizing ATs in the home.

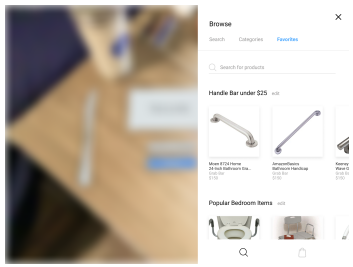
***Keywords*:** augmented reality; assistive technology; occupational therapy; home-modification; physical impairments

INTRODUCTION AND MOTIVATION
Occupational therapists (OTs) help people with physical impairments and disabilities (PwIDs) to maximize their

independence in daily activities through patient-centered interventions. In particular, home care OTs visit PwIDs (the users) in their homes to assess their living conditions and to recommend home modifications and adaptations that will create safe, supportive, and healing environments through using appropriate assistive technologies (ATs) (e.g., handrails, grab bars, and digital home assistance). ATs are crucial in helping people with disabilities and impairments to complete tasks and to maintain their functional independence at home. According to the World Health Organization (WHO), more than one billion people globally need one or more assistive products, and more than two billion people will need at least one assistive product by 2030 [12].

However, the process of finding and purchasing compatible ATs for clients' homes necessitates considering several factors, including individuals' disability levels and their homes' interior design. Such a process requires several home visits and iterations of AT interventions by the OTs [4]. In addition, they need to communicate the home-modification plans visually to the users. Current OT strategies for dealing with these issues are limited to providing a demonstration with randomly available ATs through paper printouts and online images of ATs (e.g., through the North Coast Medical or Amazon websites). However, this process can lead to the purchase of an AT that does not fit the user's home environment. OTs do not have access for demo purposes to the whole range of ATs available from medical-supply companies. Although these include many popular devices, by looking at 2D images only, it is difficult for potential users to imagine or speculate the application of an AT in their own three-dimensional space. The ineffectiveness of the process frequently generates non-compliance with ill-fitting interventions, and this may result in the users abandoning the products. It is critical to give users the opportunity to observe and interact with demo items if their compatibility with the home environment is to be ensured. A study by Phillips et al. [9] shows that 29.3% of purchased ATs end up unused or abandoned due to a lack of proper fit or insufficient consultation with users. Involving users sufficiently in the selection of ATS and informing them adequately about home modifications will enhance their utilization [6].

This research examined an augmented reality tool that superimposes virtual objects (ATs) onto real-world environments (users' homes) to circumvent the aforementioned drawbacks of the OTs' intervention process. This empowers the users to make informed decisions about their home interventions. To this end, we propose a tablet-based AR tool that allows OTs to search, find, and select ATs from a catalog of common ATs, and then to communicate and demonstrate their proposed home-modification plans to the users. Based on our initial ideas, on related research into AR in homes, and on interviews with OTs, we created a prototype for the first iteration of the AR tool and presented it to OTs in a participatory workshop. This provided us with feedback as to what would constitute an effective AR tool for OTs. We then implemented the OTs' feedback to prototype the current version of the AR tool, taking into consideration potential use scenarios and the features that the tool might ideally possess. We describe this process in greater detail in the following sections.



Figures 1, 2: The preliminary augmented reality prototype, developed using feedback from interviews on related work with AT in homes.

RELATED WORK ON AUGMENTED REALITY SYSTEMS IN HOMES

AR blends the digital and physical worlds in such a way that virtual objects are superimposed onto the surrounding environment to create a new real-virtual scenario [7]. Previous research into the use of AR in domestic environments demonstrated high potential for deploying AR systems in homes, and several applications have already been explored or developed for improving the experience of living at home. For example, an augmented kitchen with overlaid projections on objects can facilitate an interesting, safe, and accessible cooking experience [2], and an augmented home window can display information or facilitate personal and family communication [11]. Other studies on AR for homes have examined the customization of interior design, allowing users to model their homes by manipulating (e.g., inserting, moving and/or removing) 3D virtual furniture through an augmented image of the domestic environment [8, 10]. Colley et al. [3] explored the notion of augmented human memory by attaching contents to items that may potentially be utilized in the everyday home surroundings. Although researchers have explored the use of AR in designing home environments, only Bianco et al. [1] have shown the benefits of an AR home-modification prototype for elderly-fall prevention, while Djajadiningrat et al. [5] illustrated the challenges of patients in unassisted care at home and how an AR health application facilitates testing blood at home. Thus, the potential exists for investigating the application of AR in home health and rehabilitation contexts.

METHODOLOGICAL APPROACH AND FINDINGS

We employed a research-through-design method, i.e., an iterative approach to designing the AR tool with OTs. We started the process by interviewing OTs and developed a preliminary prototype for the AR accordingly. In addition, we conducted a participatory workshop in which we assessed the preliminary prototype and determined task structures with OTs. From this, we developed our current AR prototype version.

Semi-structured interviews

We conducted semi-structured interviews with four OTs (in their work environments) to understand the process involved in assessing PwIDs' needs, helping them with home modifications, and selecting assistive devices. We also asked them about the challenges that they encounter in this process and their typical strategies for dealing with them. None of the OTs had ever used AR, and while all OTs had experience working as home care providers, their levels of expertise varied, from expert practitioner and university professor to novice practitioner/graduate student. Each interview took 45-75 minutes to complete (with an average of one hour). After completion of each interview, the data were transcribed and organized onto spreadsheets. We analyzed and compiled the data into codes using the thematic analysis technique to examine the data closely and to identify common themes. We anonymized participants' names (P1–P4) to protect their identities.

The findings from the interviews revealed significant potential for an AR tool prototype for demonstration purposes in home intervention. The interview results revealed that having three-dimensional demos of ATs is

Figures 3-5: Images from a participatory workshop with two OTs. They interacted with the tool and identified methods of categorizing, searching, selecting, and demonstrating ATs with the AR tool.

the most effective of all strategies used by OTs to introduce ATs to users for home intervention purposes. As P1 noted, "That's the primary way that people can figure out if it's going to work for them or not." However, currently, the central method for introducing potential ATs to the clients is through online resources, and as P2 described: "I show people pictures of certain things on the internet and say, hey, there's this equipment available to you and this is what it would do. But we don't have the option to see how it functions and then they have to make the choice if they're going to buy it or not."

Some OTs take demo kits that include common items, such as grabbers, to users' homes. P4 said, "This show-and-tell allow(s) the client to visually interact and see them in the environment." However, OTs do not always have access to demo kits, and their limited resources pose a significant challenge to their ability to help users. Both P2 and P4 described how they buy equipment that they frequently recommend and "bring it to a session to demo it and have them try it." This is not an issue for OTs who work in clinics, as P2 described: "We kept some equipment on hand. In that way, even in (the) outpatient rehab department, I could show clients what a tub bench looks like. And that way, I could demonstrate." She continued: "I feel like verbally saying you need to install (a) raised toilet. It's, like, hard for people to understand what that looks like or what that is."

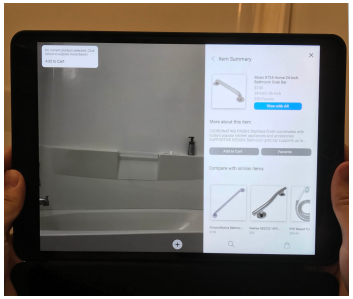
The main concern expressed by OTs related to clients' ability to accept or to integrate the AT into their lives. As P3 commented: "If you design a really cool device for someone to use but they don't see any value in it, it's going to be a dust collector." The OTs said that the high cost of ATs supports the need for virtual demos before making purchases. As P3 explained: "If I'm recommending a computer-accessible desk for him that might cost a couple of thousand, if we could put that virtually in their home and show them where it would be and see how so that they can see (it), that's perfect!"

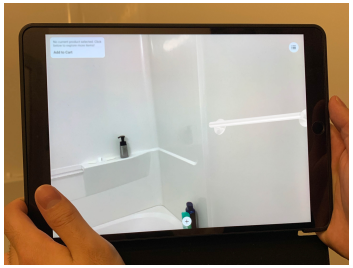
Preliminary Design of the AR Tool

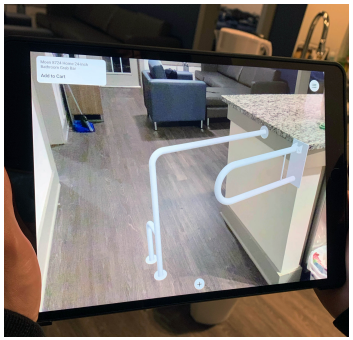
Based on the results from the interviews with the OTs, related work in AR, and our personal experience, we created a preliminary AR prototype (Figures 1, 2) using Apple's ARKit3 and the Reality Composer. The ARKit3 comes with presets of AR tools, including Swift codes for environmental scans and object placements. The Reality Composer allows developers to import 3D objects and to create interactive buttons to provide user interface (UI) and user experience (UX) flows to the AR prototype. We initially decided to create the prototype using Unity and Vuforia SDK, but the latter requires the use of a printed QR code. After discussing this issue with the OTs, we found that the QR code can be distracting and decided to use ARKit3 to place objects directly into home environments. The preliminary prototype development enabled us to go back to the OTs to collect further information on the preliminary invention idea as well as to create further refinements to the prototype through the co-design activities we describe below.

Co-Design and Assessment of the Augmented Reality Tool

We conducted a participatory workshop to make a formative assessment on the preliminary prototype and to co-design the tool with two experienced OTs (Figures 3–5). The workshop took two hours to complete, and







Figures 6-8: The current version of the home-modification AR tool, developed using feedback from OTs during a participatory workshop.

we followed a predetermined procedure to collect data on the tool requirements and features. Prior to the workshop, we developed a co-design toolkit, which included templates of a potential AR with placeholders where textual or visual information would be added. These templates enabled the OTs to share their opinions on their preferred approach for categorizing, searching, selecting, and demonstrating ATs in the clients' home environments and what other features would be required in relation to the tasks or activities to be performed. We divided the workshop into four sections as described below:

- Categorizing ATs in AR: We asked the OTs to provide us with a list of popular or common ATs for home care use and to suggest the best strategies for categorizing the ATs. The goal was to identify which ATs the OTs regularly recommend to their clients and how they would prefer to categorize these items for the purpose of searching and finding them effortlessly later.
- Searching for ATs in AR: We provided the OTs with 40 images of ATs and a template for placing the images to determine the best strategy for searching effectively for ATs in the AR tool by using different categories.
- Selecting ATs in AR: Using multiple versions of an AT (e.g., a grab bar), we asked the OTs to write down the types of information they would require when sorting and selecting ATs for demo purposes.
- Demonstrating the ATs using AR: Using the Wizard of Oz simulation method and our preliminary AR prototype, we asked the OTs to provide us with formative feedback by showing us how they would like to interact with the tool when assisting clients.

The co-design workshop enabled us to collect useful feedback from the OTs. It provided us with a detailed list of design requirements, which informed the development of the next iteration of the AR tool. This is described in detail in the following section.

DESIGN CRITERIA FOR HOME MODIFICATION AUGMENTED REALITY

The outcome of the participatory workshop with OTs provided us with six critical design requirements to include in the further development of the AR prototype (Figures 6–8), as follows:

- Browsing ATs: The OTs' preferred method for categorizing and filtering ATs is by their location in the home (e.g., bathroom, bedroom, and kitchen), followed by categories that relate to activity type (e.g., toileting, bathing, and cooking) and to the type of disability (e.g., people with spinal cord injury, arthritis, or stroke). These strategies should be particularly beneficial to novice OTs as they will enable them to explore and discover new assistive devices to share with their clients. However, experienced OTs should be able to search for ATs by using keywords in the search bar (e.g., 3-in-1 bedside commode) or by choosing a manufacturer they trust (e.g. Active Aid 10), based on their familiarity with existing ATs in the market.
- AT Information: OTs need instant access to product information, including size (full measurements), weight, and price, as each item necessitates specific assessment by the OT. For instance, when selecting a grab-bar or grabber tool, knowing the length is critical, while for a toilet seat raiser the height is important. Other factors include the materials and

installment plans that make it possible to assess the feasibility of installing an AT in a client's home.

- Demonstrating ATs to users: OTs should be able to display AT interventions (together with associated information such as measurements and price) on tablet screens and have the ability to hide information for an explicit demonstration.
- Manipulating ATs: OTs need to be able to manipulate and interact with an item in three ways: 1) move it on the iPad to adjust its position, 2) lock it into the real environment, and 3) replace it with similar items to showcase/compare products. For instance, if they were to demonstrate a bathroom-seat raiser, they would want to show two examples in succession to compare how they would fit into the space. Also, for smaller hand-held items (e.g. a rocker knife), they would like to place them side by side to note similarities or dissimilarities between them.
- Inventory of ATs: A shopping-cart type feature should show the total price of the recommended ATs. The OTs should also be able to add items manually or compare items on a list. In addition, the OTs asked for a list of favorite ATs on which to record items for future quick access.
- Other functionalities: The OTs should be able to take a screenshot of an AT's placement in the home environment, and also email or print out images of selected ATs for clients. They also wanted a video tutorial that shows first time OT users how the device is to be used.

DISCUSSION AND FUTURE WORK

Existing home modification methods or intervention plans make it difficult for OTs to provide convincing suggestions to disabled users, which leaves them indecisive about the right AT to purchase. Our recommended tablet-based AR is promising for bridging this gap between OTs' suggestions and the decisions users must make. The preliminary data collected revealed that OTs welcome the prospect of using AR in home interventions, and they shared valuable insights into how such a technology could be beneficially integrated into the process of demonstrating ATs to users in real time. This process would enable people with disability (and their family members) to make informed decisions about the "right ATs" to purchase and how to integrate them into their homes, thereby resulting in improved quality of life. We anticipate that our tablet-based AR tool would save money, time, and effort in preparing and demonstrating ATs in the home environment, thereby enabling users to envision the most appropriate scenarios before purchasing an AT. This is particularly important for users with limited financial resources. Additionally, we expect that the AR tool will reduce AT abandonment by users and facilitate AT utilization by enabling them to make informed decisions about purchasing appropriate ATs. However, further research is required for the evaluation phase of this project to observe how both OTs and users interact with the AR tool during AT interventions and home modification. Also, given the small number of participants in the co-design (two OTs), our findings have limited scope and the proposed design criteria need further exploration. At its current stage, the AR tool is ready to be tested in the home environment, and we plan to conduct a user study to test the tool's efficacy with both OTs and PwIDs during the next step in this project. Our ultimate goal is to implement the tool widely in home care OTs practices, and to empower them to provide better recommendations for clients' home interventions.

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