Towards Augmented Reality-Based Remote Family Visits in Nursing Homes

Eva Abels[1,2], Alexander Toet[1(✉)], Audrey van der Weerden[3], Bram Smeets[3], Tessa Klunder[4], and Hans Stokking[4]

[1] TNO Soesterberg, Kampweg 55, 3769 DE Soesterberg, The Netherlands
{eva.abels,lex.toet}@tno.nl
[2] University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands
[3] MeanderGroep Zuid-Limburg, Minckelersstraat 2, 6372 PP Landgraaf, The Netherlands
{audreyvanderweerden,bramsmeets}@mgzl.nl
[4] TNO New Babylon, Anna van Buerenplein 1, 2595 DA Den Haag, The Netherlands
{tessa.klunder,hans.stokking}@tno.nl

Abstract. Family visiting restrictions in nursing homes due to COVID-19-related measures have a major impact on elderly and their families. As an alternative communication means, TNO is developing an augmented reality (AR)-based solution to realize high-quality virtual social contact. To investigate its suitability for remote family visits in nursing homes, the AR-based solution will be compared to regular video calling in a user study involving elderly and their family members. Based on focus groups with elderly, family and caretakers, user experience (UX) indicators have been established to evaluate these virtual family visits, of which social presence was the most prominent. Remote family visits via AR-based and regular video calling are expected to result in different UX. It is hypothesized that participants will report the highest levels of social presence in the AR condition. If AR-based video calling is indeed preferred, TNO will continue and upscale the development of this technology.

Keywords: Augmented reality · Social XR · User experience · Social presence · Spatial presence · Elderly

1 Introduction

Due to the recent COVID-19 pandemic, stringent safety measures have been enforced in nursing homes and these visitation restrictions have a major impact on the elderly residents and their families [1]. Virtual visits via XR (extended reality, which includes virtual, mixed and augmented reality (VR, MR and AR, respectively)) communication systems offer a highly suitable solution by enabling users who are physically situated in different locations to interact with digital representations of each other in virtual environments (VEs) [2]. As an alternative communication means during and beyond the COVID-19 pandemic, TNO is developing a social XR application based on AR to realize high-quality virtual contact between the elderly and their family members.

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To successfully design a social XR application, it is essential to gain insight into its user experience (UX) [3]. For VEs, UX research has been primarily focused on the technology's capability to promote a sense of (spatial) presence ("*being there*" [4, 5]) and social presence ("*being together and having an intellectual/affective connection*" [4, 6, 7]). These subjective experiences are a critical aspect of virtual interactions [7] and measures of presence have been used as quality parameters for (comparisons between) different communication systems [8].

However, to be able to assess the UX of TNO's newly developed AR application, two issues need to be resolved: (1) while the concepts of spatial and social presence have been investigated extensively in VR environments [7], less is known in the context of AR [9] and it is unclear to what extent the findings of (social) interaction studies in VR translate to AR; and (2) currently, no UX methodology exists to evaluate social interactions in AR [2].

With respect to the first issue, some technical differences between these XR alternatives must be considered. VR environments typically replace the real world with a virtual one through immersion of the user's senses [2]. However, AR environments are unique in the sense that real and virtual elements co-exist by supplementing the real world with virtual objects, which the user can interact with in real-time [2, 9].

Consequently, this leads to different interpretations of spatial presence. In VR environments, spatial presence refers to the user's perception of physically being in the VE [4, 7], whereas in AR, the virtual objects become part of the user's environment such that it seems as if they really belong to the physical world [10]. As this research involves an AR solution, the appropriate definition of spatial presence for AR environments is maintained.

As for the assessment of the quality of social AR experiences, methods developed in VR research can be adopted as a starting point and may be adapted to make them suitable for applications in AR. Moreover, as TNO's AR solution will be applied in nursing homes, the involved user groups consist of the elderly, their families and caretakers, requiring evaluation methodology tailored to these specific users. Therefore, focus group sessions were conducted with these user groups, with content partially based on VR research. These sessions resulted in the formulation of three UX indicators to evaluate social AR experiences in this study: spatial presence, social presence and enjoyment.

In this research project, TNO's AR-based video calling solution will be compared to regular video calling, to investigate its suitability for remote family visits in nursing homes. This project is part of a collaboration between TNO and MeanderGroep, a healthcare provider in Zuid-Limburg, the Netherlands.

2 Method

2.1 Participants and Procedure

This study will include 16 pairs of participants, each pair consisting of one elderly resident and one family member. The evaluation of the technology is structured in a within-subjects design, such that each pair will undergo the two visiting conditions (i.e., AR-based and regular video calling) in counterbalanced order within a single testing day. During the virtual visits, which will last about 20 min each, the resident will be seated in

a room within their familiar living environment (a MeanderGroep nursing home) and the family member will be located in another room at the same location. After each virtual visit, the experiences of the elderly resident and the family member will be evaluated.

2.2 Technical Setup

The general architecture of the AR system is shown in Fig. 1. The resident sits in front of the AR-tablet (iPad Pro) that is positioned vertically on a stand, in between the resident and an empty chair. The elderly resident is filmed using a Logitech webcam that is attached on top of the iPad Pro. When looking at the screen, the resident sees the family member projected onto the chair, so that the family member appears to be physically present and sitting opposite the resident (Fig. 2). Two computers are used to connect the technology on both sides via the internet, to deliver the video frames from the elderly to the family member as well as the audio signals in both directions.

At the family side, the family member sits in front of a 43″ TV screen on which the resident is displayed. To record the family member, a three-dimensional (3D) RGB-D camera (Azure Kinect) is placed in front of the TV, so that the family member can be recorded and then virtually displayed in the resident's environment as a photorealistic live capture, using highly detailed point clouds. A separate local area network (LAN) is used for video and audio data transmission, ensuring a high-functioning connection.

Depth information is required to create a 3D point cloud from a 2D image. The color space (how colors are stored) and bit-depth (how much information is stored per pixel) greatly influence the quality of the depth image. To project the depth information on a video frame, the Kinect depth capture of the family member is processed in several steps, including a foreground-background removal, mapping and stitching of color and depth, conversion into HSV (hue, saturation, brightness; an alternative of the RGB color model), and erosion and dilation to remove noise and smoothen edges.

A Web Real-Time Communication (WebRTC) module transmits the frames to the elderly's side where they are received by the WebRTC reception module. Then, the frames are rendered in AR on the iPad, such that the 3D depth content of the family member is presented at the side of the elderly.

Fig. 1. Overview of the video communication system with AR between the elderly (*Person A*) and the visiting family member (*Person B*). The elderly views the family member projected onto a chair in AR on an iPad Pro, while the visitor views the elderly on a 43″ TV screen.

In the regular video calling condition, a live video connection will be established using Microsoft Teams, an online video conferencing software program. The same setup will be used as during AR video calling: the elderly sits in front of the iPad where the

family member is now presented in 2D and is filmed by the iPad front camera. The family member views the elderly on the TV and is filmed by the Kinect camera.

In both the AR and regular video calling conditions, the same screens will be used in the same orientations and the audio quality will be similar by using the same Jabra 750 speakerphones for good audio quality and echo cancellation. In the regular video calling condition, the self-view will be covered, since the AR solution also lacks a self-view. These steps are taken to ensure that the reported evaluation only pertains to the experience and not to technical differences between both viewing modes.

Fig. 2. Example of AR-based video calling: the elderly (*left)* sees the family member *(right)* projected onto the chair when looking through the AR-enabled screen of the iPad Pro.

2.3 Evaluation Methodology

The evaluation with the elderly residents will consist of observations and a short semi-structured interview. A MeanderGroep caretaker will observe (changes in) the elderly's behavior based on an adapted version of the Music in Dementia Assessment Scales (MiDAS; which assess levels of interest, response, initiation, involvement and enjoyment [11]) before, during and after the virtual visits. The interview will take place directly after each visit, in which the resident is asked about his/her experiences based on the UX indicators of spatial presence, social presence and enjoyment.

The family members will fill in a short questionnaire on the three UX indicators and a Dutch adaptation of the Networked Minds questionnaire (NMQ) [6]. This questionnaire was selected because it examines self-perception as well as perception of the other with regards to (social) presence and psycho-behavioral interaction.

2.4 Statistical Analysis

Since the elderly's experiences are prioritized, the primary outcome measures are the MiDAS observations and UX indicator scores. The family member's experiences, examined by the UX indicators and NMQ, will serve as secondary measures.

A significance level of 0.05 will be used for all hypothesis tests. Data analyses will be performed using the statistical program SPSS. A repeated-measures analysis of variance (ANOVA) will be used due to the within-subjects design of this study.

3 Expected Results

The elderly subjects are likely to experience differences in UX between family visits via AR-based and regular video calling. It is hypothesized that AR-based video calling will be evaluated more positively than regular video calling in terms of spatial presence, social presence and enjoyment (i.e., the three UX indicators). As for the observations, higher levels of interest, response, initiation, involvement and enjoyment are expected during AR-based than during regular video calling.

The experiences of the family members are hypothesized to be similar between conditions, as the conditions involve an identical setup. Therefore, no differences are expected in UX indicator scores and on the self-perception items of the NMQ. However, the items on the perception of the other might differ, such that higher levels of (social) presence and psycho-behavioral interaction are reported in the AR condition than in the regular condition, as the mode of communication between conditions did differ on the side of the other (that is, the elderly).

4 Discussion

In this study, an AR-based video calling solution will be compared to regular video calling, as an alternative communication means with the purpose to afford life-like remote family visits in nursing homes during and beyond the COVID-19 pandemic. The experiences of the elderly residents and the family members will be assessed based on UX indicators of spatial presence, social presence and enjoyment, which were derived from focus group sessions.

The hypothesis that the elderly will evaluate AR-based video calling more positively than regular video calling is in accordance with earlier research where AR-based and 2D display-based systems were compared in a within-subjects design [12]. The AR-based condition received higher ratings in terms of spatial and social presence as compared to the 2D system. However, this experiment was conducted with different user groups with a task-based setup and involved AR-based communication for both conversation partners.

The main advantage of this study is that the characteristics of the elderly population have been taken into account while developing the application and the evaluation methodology. This leads to a design aimed at providing a comfortable, positive and pleasant experience where social interaction and connectedness is promoted, which is in conformity with design principles for social VEs [2]. Additionally, this study could contribute to the development of an UX evaluation method for social interactions in AR, which can be used to assess and compare the successfulness of such social communication technologies.

The limitations of the AR system include screen size and bandwidth. Due to the iPad's screen size, the family member's facial expressions are relatively small. This

could have been improved by zooming in, but was not tested because of time and budget constraints. Also, the WebRTC bandwidth is limited and could be improved, yet by considering expert opinions on video quality this was still deemed sufficient. Furthermore, the generalizability of the findings to the general population are limited, as the emphasis is on the experiences of the elderly residents. Lastly, this study only involves a one-time experience of the technology and the outcomes might not necessarily correspond to long(er)-term effects, which should be explored by future studies.

The elderly's reported differences in UX between family visits via AR-based and regular video calling will provide insight into the differential experience of these communication methods and into the particular aspects of AR that are crucial to designate it as the favorable system. If AR-based video calling is evaluated more positively, TNO will continue developing this technology.

If the elderly report no differences in UX between family visits via AR-based and regular video calling, or if AR-based video calling is rated more negatively, then TNO will discontinue the development of the AR-based solution for nursing homes. Alternatively, this study could reveal that certain aspects of the technology need to be improved for the product to become satisfactory.

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