Evaluating Pointing Modes and Frames of Reference for Remotely Supporting an Augmented Reality User in a Collaborative (Virtual) Environment

Evaluation within the Scope of a Remote Consultation Session

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ABSTRACT

With the availability of powerful and affordable Augmented Reality (AR) devices, scenarios have become popular in which people wearing AR devices are supported by remote experts. These experts often use 2D peripherals to access the video feed of the 3D head mounted device (HMD) and to augment it with verbal or digital information. This raises the question whether tools that work for these scenarios also work for remote consultations. We conducted a study to (re-)evaluate these tools in a furniture sales consultation context. We focused on the consultant side of these settings and explored how the use of different pointing methods and perspectives affect different situations during a consultation. For this, we developed and evaluated a prototype with ten furniture store workers. Initial results show that while most usability and task load scores were even, the participants reported clear favorites for certain settings. We use these results to derive design recommendations for similar future projects.

CSS CONCEPTS

• Human-centered computing→Mixed / augmented reality
• Human-centered computing→Collaborative interaction
• Human-centered computing→Pointing
• Human-centered computing→Interaction devices

KEYWORDS

Remote consultation, remote collaboration, augmented reality, pointing, perspectives

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1 Introduction

For the use of Augmented Reality (AR), remotely supported expert-worker scenarios [1]–[5] are of interest. While these have been studied in industry and service, they are also applicable for consultation, with personalized support. However, consultation at a store might not satisfy the customer, as it is hard to imagine how a good, e.g., furniture, fits to their home and home visits are not always feasible. AR may offer a solution: A consultant could augment a customer's space by sharing the camera feed of the customer using an AR head mounted device (HMD), and the customer can preview items and provide feedback. Both need tool support to enable, e.g., placement of furniture and pointing to make the customer aware of something.

This remote interaction becomes difficult if the consultant has access to 2D peripherals but is supposed to interact with the client situated in a 3D environment. The resulting difficulties in interacting with the 3D space (e.g., setting the depth of an object) need to be overcome to enable real-time consultation.

In order to tap the potential for AR and to overcome the difficulties described above, we conducted a study to evaluate different methods for pointing at and placing 3D objects from a 2D device to find interaction modes suitable for remote support.

2 Related Work

Early on, wearable computer systems proved to be beneficial for remote collaborative tasks, with Siegel et al. [6] suggesting that a shared view of the work area and direct support for a worker strengthened coordination and cooperation. Recent research separates collaborators in these scenarios into an "expert" and a "worker". Examples for these scenarios have been studied for construction tasks [2], [7], the impact of non-verbal communication in remote settings [8] or even for expert support in crime scene investigations [5], [9]. For experts interacting from a 2D input device with workers in a 3D environment, telepointers and view perspectives are discussed in literature.

2.1 Telepointers for Remote AR Support

Remote AR support often requires the expert to place virtual pointers near the worker. Gauglitz et al. [10] describe a system enabling pointer placement inside the field of view of a tablet, showing improved task solving efficiency over using video, only. Gurevich et al. [11] also found that these „telepointers" were often combined with verbal speech to great success.

For placing telepointers within a 3D scene, one may choose to use 3D input hardware such as the "DepthSlider" [12], or 2D input devices such as a mouse with new input modalities added. Using these, the "depth" of the telepointer can be set either manually or automatically. For the former, Duval and Fleury [13] have shown that using the mouse wheel for this outperforms 3D input hardware. Setting the depth automatically can be achieved by mapping a 3D cursor ("Skitter" or "Triad Cursor" [14]–[17]) onto a surface at the position of the mouse pointer, aligning it to the surface and anchoring a 3D pointer to it.

Finally, to counteract missing spatial perception when using 2D screens, "Visual Cues" [18], [19] such as the "Interactive Shadows" by Herndon et al. [20], "Shadow Planes" used by Wither and Hollerer [21] or reflections [18] can be used, with more cues additively resulting in better depth perception [22].

2.2 View Perspectives in Remote AR Support

Gauglitz et al. [1] found that placing telepointers in the worker's vicinity with full perspective control worked better compared to ones placed directly onto the video feed. However, losing track of what the other user can see [23] or enforcing a perspective differing from the worker's, [24] can lead to loss of mutual awareness. In addition, Shepard and Metzler [25] have shown that the time needed to distinguish two differently rotated 3D objects or viewing them from different perspectives requires linearly more time the further they differ rotationally.

Schafer et al. [26] differentiated "frames of reference" as "egocentric views" for first-person perspectives and "exocentric views" for external perspectives. They observed better collaboration and awareness if both participants used an egocentric view, less mental effort if only the expert used an exocentric view, and faster task completion if at least the expert used an exocentric view. Yang and Olson [27] found that exocentric views were more efficient in search tasks, while egocentric views helped navigation for retrieval.

3 Enabling AR Support for Remote Furniture Sales and Consultation

For this work, we focused on how to support an online consultation in a furniture sales context with proper mechanisms. Based on this, our central research question is:

RQ1: "How can a consultant, using a 2D interface, support a remotely located customer wearing a 3D HMD in a consultation setting?"

3.1 Furniture Sales and Consultation

For this study, we worked together with a furniture reseller selling highly configurable upholstery. Sales are mainly done via personal consultation in the furniture store, as online furniture sales have remained low [28], possibly due to the lack of consultation options. An initial field visit revealed that most customers bring very little information on their home environment, resulting in a difficult, long and potentially unsatisfactory consultation.

3.2 Supporting Remote Consultation

In the study presented here, we focused on the consultant side of the consultation, exploring which telepointers and perspectives work best. For this, we refined RQ 1 further:

RQ1.1.: "Which pointing methods work best for different situations during a remote consultation, and how do they affect it?"

RQ1.2: "Which perspectives work best for different situations during a remote consultation, and how do they affect it?

To answer these questions, we compared the pointing modes and perspectives described above in a simulated consultancy situation (see section 4). We expected similar differences in perceived usability, mental demand and consultation success as reported in earlier studies (see section 2): For guiding a customer through a room, we expected an approach similar to Duval's and Fleury's study [13] to be preferred due to the freedom to place telepointers at head height in any situation. We assumed that a mode with automated depth, e.g., Bier's snap-dragging skitters [15] would be preferred for pointing out details on objects, since placing it inside or in front of the object is ruled out right away. For the perspectives, similar to the findings presented in section 2.2, we assumed that consultants would prefer an egocentric view for placing objects in spots dictated by the customer, since no focus and perspective shift would be required. If the consultants were to suggest a placement spot by themselves, we expected them to prefer an exocentric view due to the improved overview and no need to direct the customer.

3.3 Implemented Tools

For the customer side of the prototypes, we used the "Microsoft HoloLens" as a device capable of vision-based tracking [29] to properly augment the homes of customers. The prototypes were developed in Unity [30] using C#.

The modes we implemented differed in how the third axis (depth) is manipulated while pointing at or placing objects, with one mode allowing for it to be set manually (manual depth, MD), and the other setting depth automatically (assisted depth, AD).

For pointing, we implemented a "Manual Depth Pointer" (MDP, Figure 1, top left) and an "Assisted Depth Pointer" (ADP, Figure 1, top right). MDP takes the mouse cursor position over the camera feed to calculate X- and Y-axis positions, while the Z-axis can be set using the scrolling wheel of the mouse, similar to [13]. As a depth cue, we display a simplified "shadow" of the pointer on each wall around it [20], [21] (see Figure 1 top left). ADP also uses the cursor for the X- and Y-axis positions of the pointer, and uses an approach similar to [14] to set the depth: The pointer is placed on and snapped to the surface directly "behind" the cursor (e.g., the cushion in Figure 1 top right).

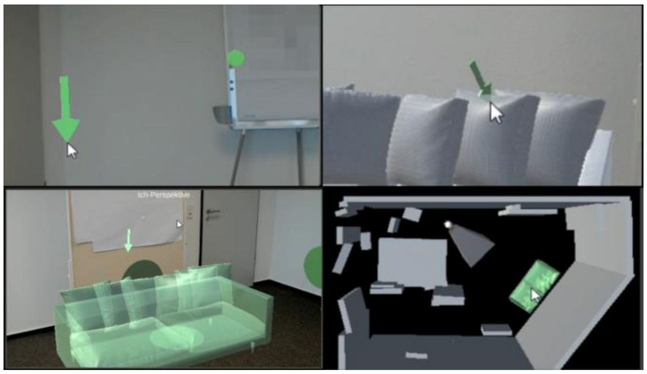

Figure 1: The different tools tested: Manual Depth Pointer (top left), Assisted Depth Pointer (top right), Manual Depth Egocentric Placement (bottom left), and Assisted Depth Exocentric Placement (bottom right) including the different perspectives taken by consultant (top view, fixed rotation) and client (represented by circle and frustum).

The perspectives were incorporated into furniture placement modes and separated into "Manual Depth Egocentric placement" (MDEG, Figure 1, bottom left) and "Assisted Depth Exocentric placement" (ADEX, Figure 1, bottom right). MDEG works almost exactly like MDP, with the third axis for placement being constrained to ground level (see Figure 1 bottom left: Furniture can only be placed on the floor). ADEX makes use of an exocentric, top-down view to facilitate placement (Figure 1 bottom right). Furniture can be placed similarly to ADP, and as in MDEG the ground serves as the only surface furniture can be snapped to. Since it makes sense to constrain placement of large furniture to the ground, there were only two axes to control. Therefore, there were enough degrees of freedom for the user of the mouse to place furniture in egocentric placement, and we did not combine it with assisted depth for this reason. Likewise, there was no need for exocentric placement with manual depth. We therefore did not test these combinations. Also note that, when testing the exocentric view, it was activated automatically upon entering placement mode.

4 Study

We designed a staged remote consultation to emulate a real-life scenario, based on our observations in the furniture store. The instructions for the consultant were as follows:

1. Using the pointing tool, find and recommend a suitable spot to place a couch inside of the room of the customer.
2. Place a couch in the spot found in step one.
3. The customer will tell you that they want the couch in a different spot. Fulfill their wishes.
4. Point at a detail on the couch and ask the customer for confirmation if they can see the same detail.

We set the spots for pointing and placement beforehand. Step one and four served as variables for comparing the pointing modes and steps two and three for comparing the perspectives. Modes with similar controls were bundled as the "Manual Depth Toolset" (MDT, including MDP for pointing and MDEG for placement) and "Assisted Depth Toolset" (ADT, including ADP and ADEX). The study included two runs, with one toolset used for the four tasks in each run and an alternating starting order to counterbalance order effects.

4.1 Course of Study

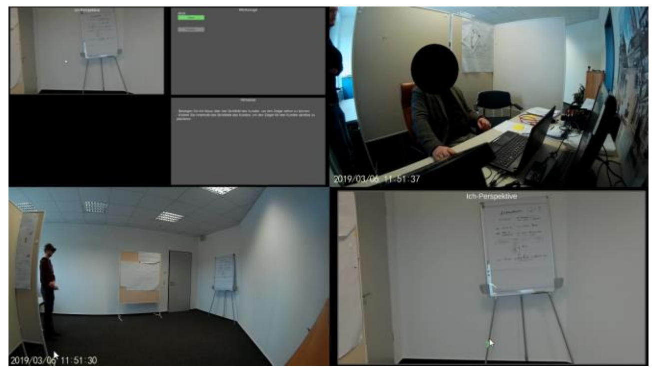

Figure 2: Consultant screen (top left), consultant workplace (top right), customer area (bottom left), customer field of view (bottom right)

The study was run with 10 workers of the furniture company, and a research assistant with set instructions "played" the customer. The consultant worked on a laptop and the customer with the HoloLens. Each run took place within the same room, separated by pin boards to shield the views but not the voice communication of the participants from each other.

For data collection, we recorded the screen of the consultant side and the customer's room. After each run, the participants were asked to fill in a questionnaire which had the participants rate usability (from 1 to 5) for each individual tool, overall perceived success (from 1 to 5) of the consultation and task load (using raw TLX [31]). We did not use methods like the SUS [32], since we wanted to ask specific questions directly referencing the pointing modes and perspectives. In concluding interviews, we collected preference data from the consultants.

5 Analysis

We used the t-test and the Wilcoxon signed-rank test for statistical analysis. The interviews were transcribed and examined for key statements. As described in section 4, the tests compare the toolsets MDT and ADT.

5.1 Work Load

The TLX results show a significant difference in perceived mental demand, with it being significantly higher for the ADT ($M = 9.30$, $SE = 1.984$) than for the MDT ($M = 4.18$, $SE = 1.267$), $t(9) = -2.39$, $p = 0.041$. We attribute this difference mainly to the perspective changes in placement (see section 2.2), which was caused by the consultant looking at the room from above with a fixed rotation of the room, while the client looks at the furniture being placed from a different angle (see Figure 1 bottom right). Our observations support this: For both placement scenarios, the shifted perspective caused by ADEX troubled many consultants. This could be explained by the already mentioned [25] additional time needed for mental rotation while also having to direct the customer. The other scores show no significant differences, which we attribute to the short and easy nature of the tasks.

5.2 Usability & Perceived Success

We asked the consultants to rate pointing for utility when “directing customer position/gaze” and “pointing out furniture details” and the perspectives when placing an object based on the “consultant’s recommendation” and “customer’s wishes”. We did not observe any significant differences in our results. This could be attributed to all scores being rated at a 4 or higher on average. Asking the participants to rate their perceived success for each toolset yielded similar high ratings and no significant differences. We attribute these results to a possible novelty effect stemming from the use of AR and a remote consultation.

5.3 Interview and Observation Results

In the interviews, we looked for similarities in the opinions of the individual consultants (hereby referred to as “C1-C10”). For the pointing modes, the results show an inclination towards the ADP in all situations. For directing the customer (eight preferred ADP), many consultants reported the ADP to be “more intuitive to use” (C1, C4, C6-C9). Many users stated that while the MDP allowed for more freedom and precision, they preferred “not worrying about having to set the pointers’ depth at all” (C1, C4, C6, C7, C10). For pointing out furniture details (six preferred ADP), C4, C6 and C8 rated the ADP as being “more intuitive to use”. Interestingly, most participants used the pointer for confirmation and used voice-only communication for directing. This differs from previous research which showed that a pointer is superior to verbal communication in collaborative tasks with an HMD user [33]. This could be explained by the fact that all information needed for pointing was already present, and the pointing mechanism was perceived as redundant (see [34] for redundant curs). However, most participants commented that a pointer “is definitely needed” (C2-C10).

The perspectives show a clear preference of ADEX over MDEG (nine preferred ADEX) when placing a piece of furniture in a spot recommended by the consultant. Most participants reported ADEX to “be more intuitive to use in this situation” (C1, C2, C5-C10), since it would be easier for them to “obtain an overview over the customer’s room layout” (C3, C7, C8, C10). For fulfilling customer wishes, more users leaned towards MDEG (seven preferred MDEG), stating that “the customer will already look at the spot they want a piece of furniture in” (C3, C7, C9, C10) and as such, there was no need to direct the customer’s position and gaze. Some participants reported that since “they look in the same direction as the customer does” (C1, C3, C5, C10), it simplified the placement process for them. This can again be explained with the additional time needed for mental rotation [25], and was underlined by our observations: We counted questions like “Is this spot okay?” resulting in significantly fewer confirmations for MDEG ($M = 2.6$, $SE = 0.34$) than for ADEX ($M = 4.1$, $SE = 0.623$), $t(9) = -2.666$, $p = 0.026$.

6 Discussion

While our expectation for RQ1.1 did not hold true, most users seem to prefer intuitive over free but more complicated pointing. More depth cues might make the latter more appealing for future projects. A surface-aligned grid similar to the shadow planes shown in [21] might prove to be beneficial. Additionally, granting access to multiple pointing modes should be considered.

Next, our expectation for RQ1.2 held true, since we observed different preferences for each perspective based on which situation was currently at hand. Providing both MDEG and ADEX as options should be considered to support the constant focus shift during a consultation. The perspectives could always both be active or incorporated as toggle-able modes, with the “inactive” mode staying in view in a smaller window.

6.1 Limitations and Future Work

For future work, the customer side of the remote consultation process remains to be evaluated, especially if both sides can manipulate the scene. Inviting consultants from different stores should also be considered. Finally, different input and hardware options need to be considered, both for the consultant (more displays, VR) and the customer (HMD with larger field of view).

7 Conclusion

We presented insight into whether different pointing methods and perspectives already known from remote expert-worker scenarios are usable for remote, AR supported consultations, as well. We compared two pointing methods and two perspectives for the consultant side of the consultation in different situations, expecting different rates of approval for different situations.

We conducted a subjective study with 10 participants in the “consultant” role in total, while an assistant played the customer. Our results show no significant differences in usability for using different tools in each situation, but an increased mental effort when using exocentric views. Direct comparison of the participant’s preferences showed a strong preference for a surface-constrained pointing tool under all circumstances. For placing objects recommended by themselves, consultants strongly preferred an exocentric view, while they mostly preferred an egocentric one for placing objects in spots specified by the customer. These findings can be used in future research on remote consultations and for actual consultation firms to provide a better experience for their employees.

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