Evaluation of Shared-Gaze Visualizations for Virtual Assembly Tasks

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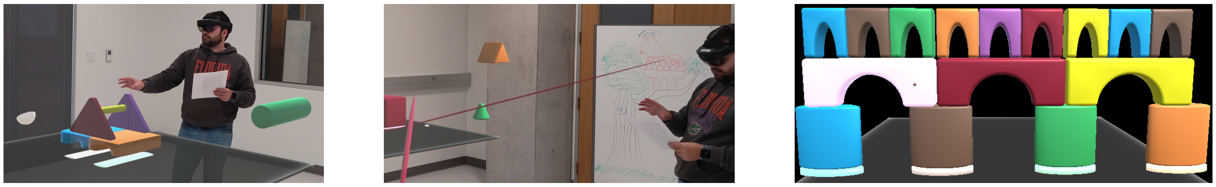

(a) Catapult assembly task.

(b) Constant ray and house assembly task.

(c) Aqueduct model and gaze hover.

ABSTRACT

Shared-gaze visualizations (SGV) allow collocated collaborators to understand each other's attention and intentions while working jointly in an augmented reality setting. However, prior work has overlooked user control and privacy over how gaze information can be shared between collaborators. In this work, we examine two methods for visualizing shared-gaze between collaborators: gaze-hover and gaze-trigger. We compare the methods with existing solutions through a paired-user evaluation study in which participants participate in a virtual assembly task. Finally, we contribute an understanding of user perceptions, preferences, and design implications of shared-gaze visualizations in augmented reality.

Index Terms: Human-centered computing—Visualization—Collaboration—Augmented reality

1 INTRODUCTION

With the advent of commercial augmented reality devices, collaborative teams are beginning to see a rise in mixed-reality technologies employed to facilitate group work. Augmented reality devices are capable of overcoming the constraints of situated displays. The devices allow collaborators to interact with virtual content while viewing the real world, resulting in higher user engagement [1]. However, head-mounted displays, a type of augmented reality device, tend to suffer the limitation of occluding eye contact between collaborators. Additionally, during collaborative tasks, eye contact may not always be accessible since collaborators may be focusing on the task [8].

Eye contact is a fundamental human trait that is essential to social and group interactions. Observed changes in eye movements between members provides an influential non-verbal cue that affects the decisions that are made [6] and allows collaborators to gauge each others' intentions [3]. Thus, there is a need for developing gaze-visualization techniques for collaborators working with head-mounted displays [8].

Prior work has visualized gaze in augmented reality headsets [5,2] and shared displays [8]. Gaze visualizations have been used for observing the impacts of virtual gaze cues on face-to-face interactions [5], focusing multi-user attention to similar looking objects [2], communicating cues to collaborators [8, 7], and asymmetric collocated interactions [4]. Despite the substantial progress in developing gaze visualizations, prior methods suffer from lack of control [5,7,4], balancing performance and user preferences [2], and privacy issues [8]. To this end, we examine gaze hover as a method of overcoming the privacy issues in current shared-gaze visualizations by only highlighting objects relevant to the task and gaze trigger as a method for providing users a hands-free approach of visualizing their current gaze.

In this work, we conducted a study with eleven participants and found that users showed mixed preferences over the shared gaze visualizations examined. Based on our findings, participants' preferences depended on their priorities during the assembly task. Using results from our evaluation, we conclude by providing design recommendations for developing shared-gaze visualizations in augmented reality headsets.

2 SYSTEM DESIGN

Two Microsoft Hololens 2 with a 50-degree field of view and a 75 Hz rate were used for the head-mounted displays. The Hololens were synchronized to the room by starting the Unity application in the same physical location. Additionally, Microsoft Azure spatial markers were used to communicate spatial information across the Hololens devices.

A virtual assembly task was conceptualized and developed using Unity 3D engine. Details about the virtual assembly task are presented in section 3. The application communicates the positions and actions of both collaborators. Microsoft's mixed reality toolkit was used for eye-tracking and hand-gesture recognition. The application allowed users to pickup virtual objects by making a pinch gesture.

We implemented three methods for visualizing gaze to collaborators: *constant ray*, *gaze trigger*, and *gaze hover*. The *constant ray* condition projects a ray (shown in Figure (b)) from the headset to the point in space the user is currently focusing on.

The *gaze trigger* shares the same ray visualization as the constant ray. However, with gaze trigger, the ray is only displayed if a user focuses on a point in space longer than a set threshold. For our study, a threshold of 1.7 seconds was selected based on piloting. Once a user looks away, the gaze trigger is turned off, and the timer is reset.

The *gaze hover* does not display a ray but instead highlights objects a user is currently looking at. When a user gazes at an object, the color of the virtual object is saturated causing it to stand out from other objects (shown in Figure (c)).

3 EVALUATION

Eleven participants (6 male, 4 female, 1 Non-binary) were recruited from a local university campus and ranged between the ages of 19-27 (Mean = 23.45, Std. Dev. = 2.71). The study protocol was approved by our local Institutional Review Board.

The user evaluation consisted of a within-subjects study consisting of two participants working together to complete three assembly

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tasks while using one of the three eye gaze visualizations. The order of visualizations was counterbalanced using a Latin Square. In the first task, participants were asked to build a simple house. The second task was to build a catapult, shown in Figure (a). Finally, the last task was to build an aqueduct (Figure (c)). Different colors were used to represent the various components of the structures. Tasks became increasingly more complex as the study progressed. An assembly task was chosen because it allows for objects to be occluded in a 3D space, in contrast to prior work that investigated the effectiveness of gaze visualizations through 2D tasks [5, 7, 4]. Additionally, assembly tasks are complex and require users to search for items and orient them while aiming to maintain awareness of each others' physical presence. After completing each assembly task, participants were asked to complete a survey based on prior work [5]. At the end of the study, participants ranked the conditions and provided an explanation for their choices.

4 Results

We did not find any significant difference in the survey results between the control (constant ray) conditions and the alternate conditions (gaze hover, gaze trigger). However, we noticed trends ($p < 0.25$) in four out of the eleven questions from the survey: *(Q2) My partner's intentions are accurately represented to me*, *(Q6) It is easy to observe my partner's attention*, *(Q7) It is easy for my partner to observe my attention*, and *(Q8) I react to partner frequently*.

For Q2, participants reported the gaze-hover as being a less of an accurate representation of their partner's intentions than the other two conditions. A further look into the post-study survey showed mixed opinions. For instance, one participant appreciated the constant ray and remarked on how the gaze-hover made it difficult to focus on the color of the objects. Alternatively, despite rating the gaze hover as a less accurate representation of their partner's intentions, P5 enjoyed how the "[gaze hover] was intuitive, and responded to the thing I was looking at..." and ranked it as their preferred visualization method.

For questions Q6 and Q7, participants rated the gaze trigger as being a more difficult method of observing each other's attention compared to the other conditions. We saw a common trend of participants finding the trigger to be distracting. For example, P3 found the other two conditions "faster and more efficient" since they didn't have to wait for the visualization to respond. Additionally, P7 appreciated the other two conditions because they were "more intuitive."

For Q8, participants rated gaze hover and gaze trigger as having less of an effect on their reactions to other participants compared to the control condition. We can gain a better understanding of participant perceptions from P9 who strongly disagreed with the survey question: "...I put constant ray last because although it wasn't very distracting with this task, I can see how it can get distracting with more complex tasks..."

Finally, from our post-study survey, users overall did not seem to show any preference between one condition over the others.

5 Discussion and future work

From our findings, we see that participants did not have a specific preference for one condition over another. Each condition presented pros and cons to the situation that would be beneficial in their own unique way. For example, participants who preferred an instant view of gaze visualizations were satisfied with the constant ray. Alternatively, some participants found the constant view of their eye-gaze to be distracting and found the gaze hover to be intuitive.

Regarding our observed responses from our survey, we provide a couple design recommendations to alternative gaze visualizations. First, we recommend designing gaze visualizations that do not occlude the object the user is currently looking at. For example, a sufficient alternative to the gaze hover would be creating a visualization that borders the edges of the current object being observed. The border approach would allow users to still view the object while communicating to other users their current perceptions.

Secondly, when designing a hands-free trigger-based gaze visualization (e.g. gaze-trigger), communicating to users the current state of the condition would help demonstrate the functionality of the visualization. Also, implementing a trigger independent of time may provide a more flexible and reliable visualization. For example, creating a hybrid gaze hover/trigger where the visualization is activated when an object is recognized.

Our work presents a couple of limitations that can be altered and reevaluated for future study. For instance, participants found the gaze trigger to be confusing and difficult to understand. Their confusion can be attributed to the fact that gaze trigger was attached to a simple focus timer. Regardless of participants' intents, the gaze trigger would automatically shut on and off, affecting participants' perceptions of it. Additionally, the gaze hover occluded the color of objects, which participants found to be an obstacle when determining which object to look for and place during the assembly tasks.

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