# Augmented Collaboration in Shared Space Design with Shared Attention and Manipulation

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**ABSTRACT**
Augmented collaboration in a shared house design scenario has been studied widely with various approaches. However, those studies did not consider human perception. Our goal is to lower the user's perceptual load for augmented collaboration in shared space design scenarios. Applying attention theories, we implemented shared head gaze, shared selected object, and collaborative manipulation features in our system in two different versions with HoloLens. To investigate whether user perceptions of the two different versions differ, we conducted an experiment with 18 participants (9 pairs) and conducted a survey and semi-structured interviews. The results did not show significant differences between the two versions, but produced interesting insights. Based on the findings, we provide design guidelines for collaborative AR systems.

**Author Keywords**
Collaborative AR; Human Perception; Shared Space Design
**ACM Classification Keywords**
• Human-centered computing ~ Mixed / augmented reality, Collaborative interaction, Interaction techniques

## INTRODUCTION

There have been growing research interests in augmented collaboration. Researchers have developed various systems for designing a shared space. A significant number of them used an AR or VR technology, which is suitable for providing a 3D view of a house. Some researchers used markers for detecting objects and placing them inside the house [7, 8]. More recently, the collaborative design of a house between novices and experts [9, 10] as well as normal users [12] have been studied. In augmented collaboration, providing enough feedback is crucial for certain information shared between users. This is because human perception can only process objects that attract a lot of attention. However, there have been few studies considering human perception in house design scenario. We adapted attention theories on visualizing head gaze and selected objects, then investigated whether a user's perceptual load is lowered by 1) collaborator's head gaze looming or 2) non-selected objects becoming more transparent. We also studied whether 3) adjusting manipulation speed based on the distance between HoloLens and object provides easier control of objects. With these criteria, we evaluated our system in a user study.

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## SYSTEM IMPLEMENTATION

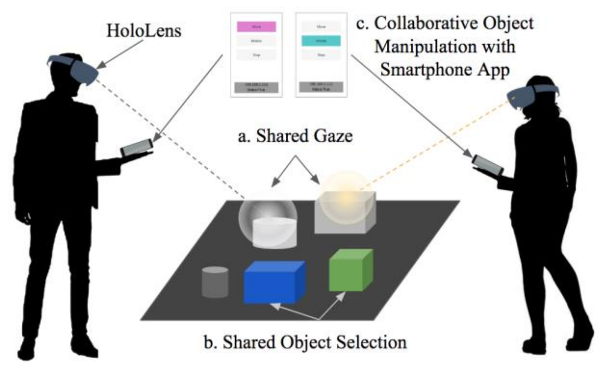


**Figure 1. System Concept**

Our system provides collaborative experience in three key features: shared gaze, selected object, and collaborative object manipulation. System concept is illustrated in Figure 1. While previous studies used several cameras [7, 8, 9] and mobile tablets [11, 12], we use HoloLens, which could be a more efficient device for providing a more shared and collaborative interaction between multiple users [1]. Multiple HoloLens share data with mixed reality toolkit-Unity sharing service. For precise manipulation of objects, we use a smartphone as a controller because it is more effective than other methods and has shown good usability [4, 5, 6]. Android accelerometer data is transferred to HoloLens using Unity network.

Each user's head gaze data of HoloLens is shared as a sphere. Each sphere can be easily recognized with a unique color (local: white, remote: yellow) as shown in Figure 2(b). A user can select an object with the light sphere selection such as SQUAD or spotlight approach [2, 3]. Object selection status is also shared between users to indicate which object is selected. If a user does the air-tap gesture which is supported by HoloLens, an object that has a minimum distance from the center of the sphere is selected and changes its color (local: blue, remote: green) as shown in Figure 2(c). Furthermore, our system allows multiple users manipulating objects together. A smartphone is used as a remote controller for translation and rotation of an object with an Android application as shown in Figure 2(e). If a user selects an object with HoloLens, the selected object can be moved or rotated by pressing the 'Move' or 'Rotate' button and then tilting the smartphone right/left/up/down or right/left respectively. It can also be stopped by pressing the 'Stop' button.

Our system supports augmented collaboration in space design with two versions regarding the three key features previously mentioned. Version 1 provides default features, while version 2 provides additional features; 1) the sphere of the remote user is looming for the better perception of sphere by the local user, 2) non-selected objects become more transparent to decrease the perceptual load of the user as shown in Figure 2(d), and 3) a user can control speed by moving closer to the object to decrease the speed or moving away from the object to increase the speed.

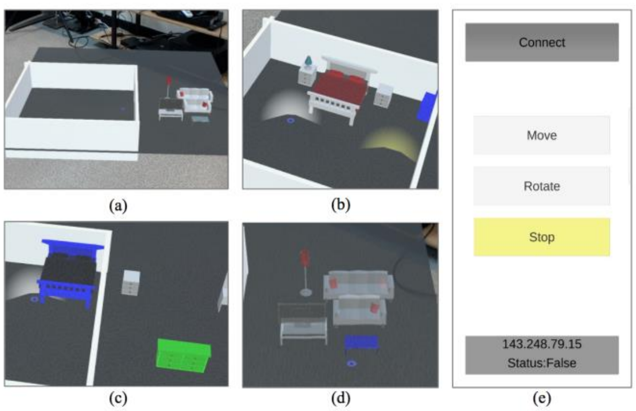


**Figure 2. System Features**

## EXPERIMENT DESIGN

In our experiment, we compared user's perception of shared information with two versions of the system. For each version, we used a different shared space such as a living room (Figure 2(a)) or a bedroom (Figure 2(b)) so that the tasks do not overlap. In addition, we randomized the order of space in the experiment. A total of 18 users (in 9 pairs, male: 12, female: 6) with age ranging from 19 to 34 (M: 22.89, SD: 4.19) participated in our study.

Following the instructions on how to use HoloLens, we gave each pair of participants the task of designing a shared space together on version 1 and 2 for 10 minutes respectively. After the experiment, participants answered post-task questionnaires (Q1: It was easy to perceive what the other person is watching, Q2: It was easy to perceive which item the other person selected, Q3: It was easy to manipulate (move/rotate) the item) for each version, in 7-point Likert scale (1 being strongly disagree and 7 being strongly agree). In addition, we gathered subjective feedback on our system's features (Q1: Gaze visualization as a sphere, Q2: Non-selected objects changing more transparent, Q3: Selected objects having different colors, Q4: Manipulation speed being changed according to slope) in 7-point Likert scale (1 being not helpful) and 7 being very helpful). Then we conducted semi-structured interviews for 20 minutes for each pair and gathered in-depth feedback on our system and suggestions for improvement.

## RESULTS & DISCUSSION

To investigate whether there is a difference in user perception between the two versions, we conducted a t-test on the answers from the post-task questionnaire. We found there is no significant difference between all three questions with p-value 0.160(Q1), 0.149(Q2), 0.442(Q3). Mean values of subjective feedback for each question were 3.667(Q1), 4.056(Q2), 6(Q3), 4.944(Q4) with standard deviation 1.328, 1.626, 1.085, 1.474 respectively. Participants generally thought it was useful to have a color difference for selected objects and the ability to change the speed of object movement. However, they felt head gaze sphere and transparent non-selected objects were less useful.

With semi-structured interviews, we gathered more insights into the reasons for the results. First, although we assumed users' attention will be on head gaze point, head gaze is different from actual eye gaze and most participants did not focus on their own or other's head gaze. They just used head gaze for selection of an object. For non-selected objects becoming transparent, some said it was useful for choosing an object that is overlapping with another object. But most participants did not recognize this feature because the hologram itself is already quite transparent. Lastly, user satisfaction on changing the speed of object movement was very varied for each individual. While some participants found this feature very useful, others did not because the task was limited in time (10 minutes) and simple. Based on these results, we suggest design guideline in the last section.

## COLLABORATIVE AR DESIGN GUIDELINE

1. *Head gaze is for selection and maybe not for sharing*: User's attention on a certain object heavily relies on actual eye gaze, not head gaze. Therefore, providing head gaze point for shared attention is not that useful. Instead, sharing actual eye gaze can support better collaboration.

2. *Data sharing in the focus of attention*: While most participants were aware of selected objects changing color because they focused on the objects, they were less aware of head gazes. Because HoloLens provides an immersive experience, it is hard to recognize small changes made in the peripheral area of attention. Therefore, directly sharing data in the focus of attention can be easier to perceive.

3. *Be careful of changing the transparency of objects*: Changing the transparency of non-selected objects is one of the popular methods for lowering user's perceptual load in 2D interaction. However, this might not be true in AR because holograms are quite transparent. Other mechanisms such as pointing with an arrow may be more suitable.

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