IoT and Augmented Reality:
Agents with Pervasive Awareness, Appearance, and Abilities

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Problem Statement

The sense of ***Social/Co-presence*** in **augmented reality (AR)**—how much users feel as if they are together with virtual entities in the simulated environment—is an important measure to evaluate the AR experience and has been extensively studied. Recent advances in display technology, e.g., optical see-through AR head mounted displays (HMDs), enable us to achieve AR effectively and efficiently with its compact and convenient form factor. There are, however, still many limitations to improve the perceived social presence with virtual entities, such as a **narrow field of view** of the HMDs and **lack of multimodal sensory feedbacks**.

Objectives & Research Questions

The goal of our research is to address some of the limits of AR HMDs, specifically the Microsoft HoloLens, and to examine the effects of the limits on the sense of social presence in AR, particularly about the peripheral view through the HMD, vibrotactile feedback in AR, and the environmental lightings.

Here are the overall research questions.

- **RQ1**: Can a light shield that blocks the periphery of the HoloLens increase social presence and compensate for lack of vision?
- **RQ2**: Can vibrotactile feedback on the floor increase social presence and compensate for a limited visual field?
- **RQ3**: Does blocking the peripheral vision in the HoloLens have the same effect as turning off the lighting in the environment?

Hypotheses

- **H1**: ***Higher social presence*** for the conditions with the **vibrotactile feedback** than without it.
- **H2**: ***Higher social presence*** for the conditions with the **limited central lighting** than the full lighting.
- **H3**: ***Higher social presence*** for the conditions with the **restricted field of view** than the open periphery.

Experiment

- 22 participants (9 female, 11 male; ages 18 to 41, M = 26.1, SD = 5.90)
- Task: Participants performed a task to search for a virtual kitten in AR among 12 cardboard boxes on a bookcase.
- Different virtual creatures appear in AR, such as virtual bats, rats, spiders, and scorpions.

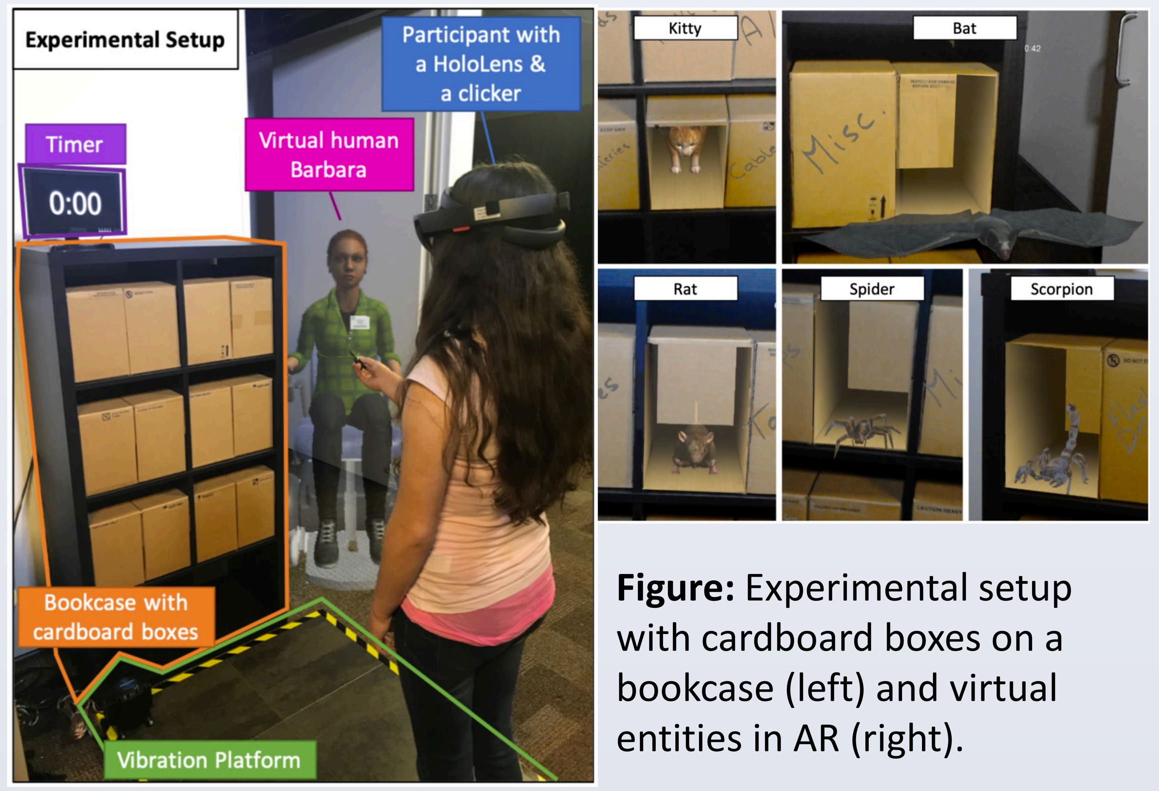

Figure: Experimental setup with cardboard boxes on a bookcase (left) and virtual entities in AR (right).

- Within-subject design with 3 independent variables (8 conditions)
  - **Peripheral View** (Restricted, Unrestricted): A black fabric cover to restrict the user's view on the HoloLens.
  - **Vibrotactile Feedback** (On, Off): A vibrotactile inducer equipped on the floor to make vibrations when virtual creatures landed on the floor.
  - **Physical Lighting** (Full, Central): The environmental ambient light for the full lighting condition; a directional spotlight lamp for the central lighting condition.

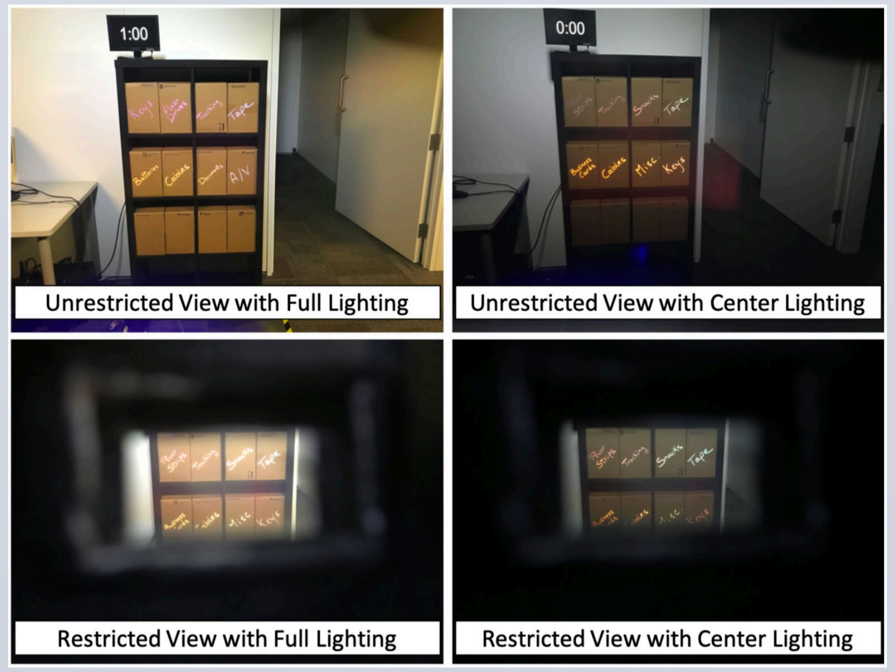

Figure: Participant views regarding the peripheral view and physical lighting.

Results

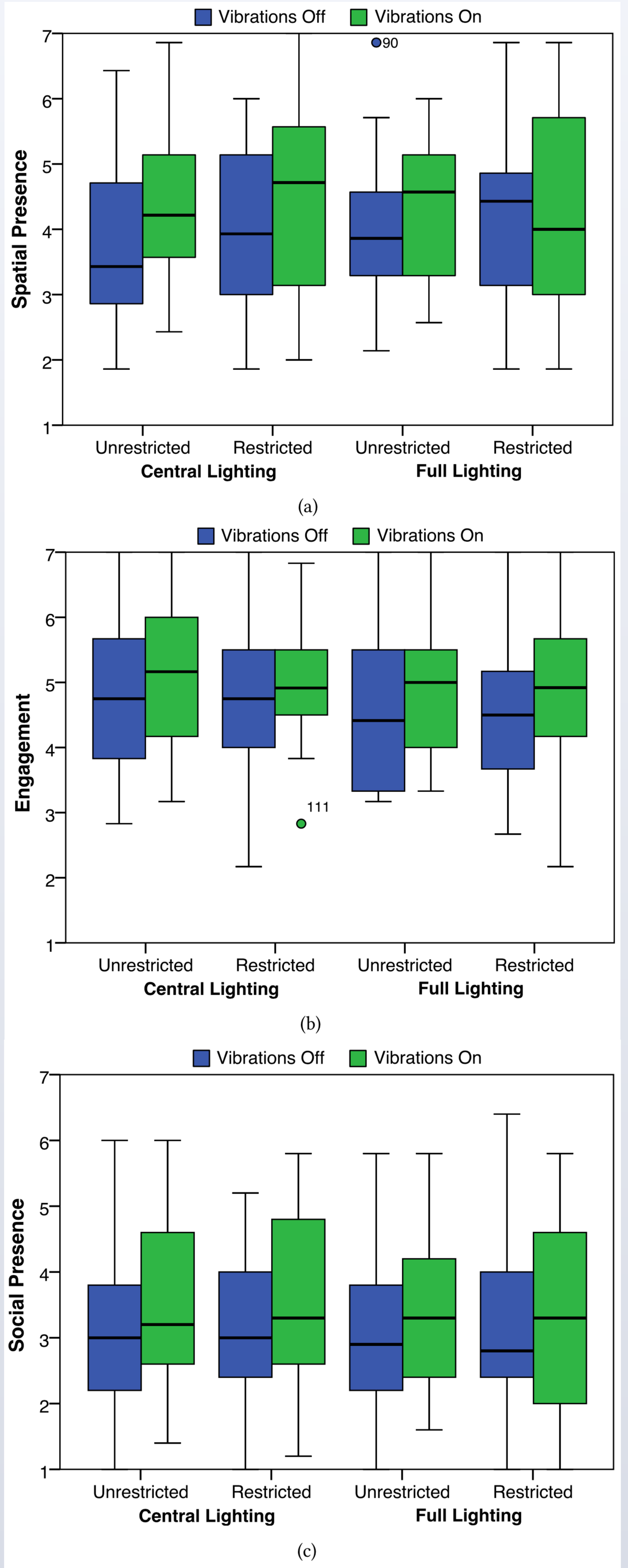

Figure: Participant-reported scores for (a) spatial presence, (b) engagement, and (c) social presence.

- **Vibrations** on the floor improve:
  - **Spatial Presence** (***p=0.001***),
  - **Social Presence** (***p=0.017***), and
  - **Engagement** (***p=0.032***).
- **Central Lighting** (deemed down) improves:
  - **Engagement** (***p=0.048***).
- **Avoidance behaviors**:
  - Pulling their head/torso backwards in 4.6% of the participant trials.
  - Moving their head/torso sideways in 12.5% of the participant trials.

Conclusion

It is important to investigate related visual technologies that have the potential to increase co-presence and reduce perceptual differences between virtual and real objects in AR. Our results show two ways we can effectively increase engagement: vibrotactile feedback and strategic lighting. Furthermore, the results in this experiment show that through vibrotactile feedback, the sense of spatial presence and social presence are increased. For future work, it is important to identify the benefits of larger fields of view in future AR headsets, as well as further technological means that can create realistic haptic feedback in AR.

This research has been submitted to ACM Symposium on Spatial User Interaction (SUI) 2019 as a full paper.

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*Under Review

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