Gaze direction determination in AR-HMD based social interactions

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ABSTRACT

Gaze carries important nonverbal information required to coordinate group activity. We studied gaze interactions mediated by an Augmented Reality (AR) headset in participant dyads, and evaluated the role of expectations concerning the positioning of virtual content attended by an AR user on gaze determination. We found that gaze estimation was negatively impacted when observers were aware (or believed) that the AR userâĂŹs attention was not directed to them, but rather to augmentations

CHI'19 Extended Abstracts, May 4-9, 2019, Glasgow, Scotland UK
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positioned somewhere in between. This shows how our expectations concerning an AR user's focus of attention can impact our ability of accurately evaluating their gaze behaviours.

CCS CONCEPTS

• **Human-centered computing → Collaborative and Social Computing**.

KEYWORDS

Augmented Reality, gaze direction, theory of mind, social cognition

MOTIVATION

Gaze behaviours represent a nonverbal channel through which we communicate information on goals and mental states [1] and direct other's attention towards environmental rewards/hazards [2, 3]. Gaze is a proxy for other's focus of attention [5], and our ability of adequately interpreting gaze behaviour is paramount to successful social interactions and coordinated joint behaviour.

People's proficiency at evaluating other's focus of attention can be assisted by various forms of technology. For example, a laser pointer can aid a public speaker's presentation by highlighting his/her focus of attention on projected slides. On the other hand, other technologies can undermine this ability. Video conferences can introduce aspects of ambiguity regarding the other's gaze and focus of attention, given that web cameras are positioned above the screen and that participants do not share the same physical space.

In a paper recently accepted in Scientific Reports (doi.org/10.1038/s41598-019-39311-1), we investigated costs in gaze determination associated with use of AR-HMDs. AR interfaces can potentially introduce elements of visual uncertainty: If we see a person wearing an AR visor, we might wonder whether they are looking at real world stimuli or computer-generated graphics, and if that person is looking in our direction, we might wonder whether they are paying attention to us or to an augmentation positioned somewhere in between.

Study

We studied the interaction between gaze direction determination and an observer's assumptions of the positioning of virtual stimuli attended by an AR user. Prior research has shown that gaze perception is affected by assumptions concerning the other's focus of attention: we are more precise at evaluating other's gaze when we believe we fall within / closer to the gazer's focus of attention [4, 6, 7]. Based on this, we hypothesised that gaze estimation performance should be improved when observers believe that the AR-HMD user is fixating on holograms displayed closer to them.

We investigated this within gaze interactions between participant dyads, mediated by a Microsoft HoloLens AR headset (https://www.microsoft.com/en-gb/HoloLens). Each pair involved one participant

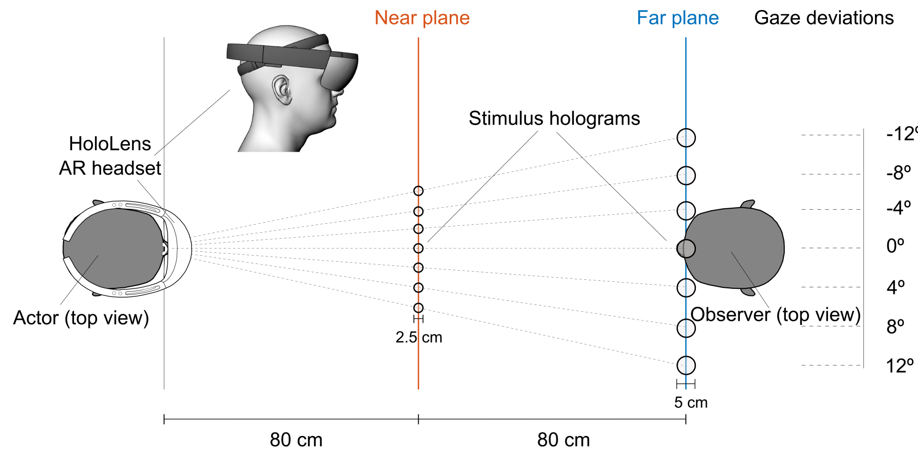

Figure 1: Experimental setup. Actor (left) routinely fixates on augmentations at 7 degrees of horizontal deviation, presented on the 'Near' or 'Far' plane. The Observer (right) classifies the Actor's gaze direction as left or right relative to a straight fixation

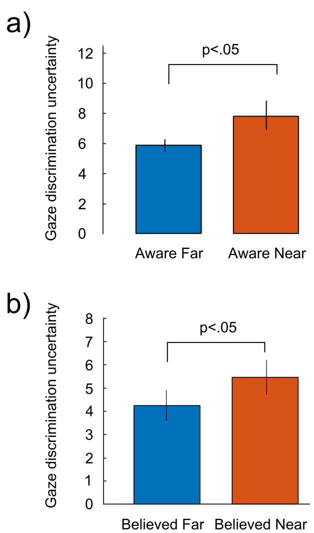

Figure 2: Gaze direction determination uncertainty (standard deviation of a cumulative Gaussian psychometric fit) as a function of a) awareness, or b) assumption, of which plane the Actor was fixating on

(the 'Actor') wearing the HoloLens routinely fixating on a set of holograms, and another participant (the 'Observer') performing gaze direction classifications of the Actor's fixation behaviours (Fig. 1). We measured whether the Observer's gaze discrimination performance was affected by his / her awareness or assumptions regarding the positioning of holographic stimuli attended by the Actor: whether the Actor fixated on stimuli positioned halfway between the pair (Near plane) or on the same plane occupied by the Observer (Far plane).

We found that gaze direction sensitivity improved when participants were aware that the AR user was attending stimuli on the Far plane (Fig. 2a). In a follow up experiment, in which stimuli were randomly assigned to the Near or Far planes, we found that discrimination performance improved only when participants *believed* that stimuli were displayed on the Far plane, irrespective of this assumption being correct (Fig. 2b). This demonstrated that a subjective expectation regarding the depth positioning of virtual content attended by the Actor modulated gaze direction sensitivity.

Implications for shared augmented experiences

These findings highlight how conditions of sensory uncertainty can impact the use of AR-HMDs in social-collaborative settings. One can appreciate the costs of reduced gaze determination in collaborative work, when considering the role of gaze in guiding cooperative behaviours and signalling the presence of potentially rewarding or harmful environmental stimuli. For example, if we assume that an AR user's gaze behaviours are directed at augmentations which happen to fall on our line of site, these behaviours might be less effective at cueing our attention towards joint-task relevant information or warning us of the spatial location of environmental hazards. These results therefore further our understanding of the impact of technology on social behaviour and gaze processing and can provide insights for the design of AR interfaces that reduce the sources of visual uncertainty that normally accompany the use of these technologies.

Attending the Workshop

My interest in attending this workshop is to learn about the current state-of-the-art regarding the use of AR-HMDs in collaborative social spaces, and what solutions have been devised to mitigate elements of visual uncertainty that accompany their use. My interests and background range across vision research, applied and social cognition (see Author Bio). I have published several works on gaze information processing, and am currently exploring perceptual and cognitive limitations associated with AR-HMD use. I believe the findings documented in this study would make a valuable contribution, and help spark a wider conversation outlining challenges and opportunities associated with AR-HMD use in shared collaborative spaces.

MAIN AUTHOR BIO

I am a Research Associate at University College London. I have an Master's degree in Experimental Psychology and a PhD in Cognitive Neuroscience, both from the University of Rome "La Sapienza". I have a background in vision research and cognitive neuroscience, and I have published 15+ papers focused on the study of brain mechanisms enabling representations of spatial and temporal magnitudes, higher order face and gaze processing, motor control and attentional orienting in humans. In my current work at the UCL-Interaction Centre I have extended my research interests to understanding the perceptual and cognitive constraints encountered with AR use, specifically in the context of non-verbal gaze interactions, attentional orienting, hologram placement and ergonomics.

ACKNOWLEDGMENTS

This study was supported by the HuMan project under the European Union's Horizon 2020 research and innovation programme, grant agreement no. 723737 (http://humanmanufacturing.eu/).

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