Peripersonal Space in Virtual Reality: Navigating 3D Space with Different Perspectives

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ABSTRACT
We introduce the concept of "peripersonal space" of an avatar in 3D virtual reality and discuss how it plays an important role on 3D navigation with different perspectives. By analyzing the eye-gaze data of avatar-based navigation with first-person perspective and third-person perspective, we examine the effects of an avatar's peripersonal space on the users' perceptual scopes within 3D virtual environments. We propose that manipulating peripersonal space of an avatar with various perspectives has the immediate effects on the users' scopes of perception as well as the patterns of attentional capture. This study provides a helpful guideline for designing more effective navigation system with an avatar in 3D virtual environment.

Author Keywords
Navigation; Virtual Space; Peripersonal Space; Perspective; Human Perception and Cognition; Eye-tracking; Gaze Analysis.

ACM Classification Keywords
H.1.2. User/Machine Systems: Human Factors; H.5.1 Multimedia Information Systems: Artificial, Augmented, and Virtual Realities

INTRODUCTION

With the emergence of virtual reality, there have been numerous 3D applications developed from games to driving simulators. 3D user interface enables us to inspect dynamic and complex information in depth, helping us understand complicated relations which 2D user interface cannot illustrate. However, the richer contexts and elements in 3D virtual space often make people feel overwhelmed with the excessive amount of information presented in higher dimension [2]. This phenomenon, called information overload, overburdens their cognitive systems and worsens the task performance by hindering information retrieval and decision-making process [6]. This may cause unfortunate results when people need to make quick decisions or take necessary actions according to the information given in the 3D virtual environments. Therefore, it is crucial to develop a system or tool that ameliorates information overload when working with 3D user interface.

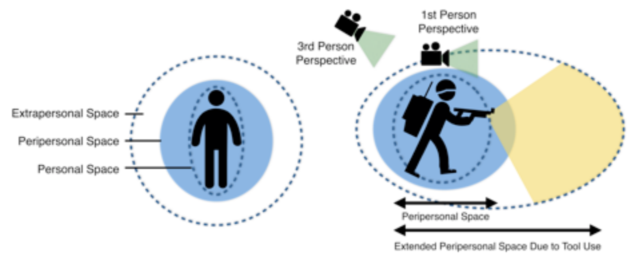

Figure 1. Peripersonal Space of an Avatar.

To reduce information overload, we should (1) develop an effective navigation system well-suited for a specific task in 3D space and (2) design an efficient 3D environment which keeps the balance between the amount of information presented and the level of cognitive capacity of the users. Since the sense of place with spatial contextual cues provide the most powerful mental guideline for the users to comprehend the 3D environment from the vantage point, there has been much research on the role of spatial characteristics such as routes, landmarks, and maps in navigation to support users' cognitive process in 3D environments [5]. However, the role of an avatar in the context of cognitive aid is unexplored, considered as a supplementary option.

GAZE ANALYSIS ON AVATAR-BASED NAVIGATION

In our previous gaze-analysis study [4], we prepared eight sequences of video clips to study what effects on the visual perception are caused by the avatar in various perspectives. We collected eye-gaze data from five volunteers with normal visual acuity (two males and three females; age=20-24 years; M=21.5 years; SD=1.48). The eight sequences shown to the subjects were: (a) a first person perspective (1PP) sequence with no avatar on a road, (b) a third person perspective (3PP) sequence with a car closer to the viewpoint of the subjects, (c) a 3PP sequence with a car farther from the viewpoint of the subjects, (d) a 1PP sequence with no avatar in an art gallery, (e) a 1PP sequence with a tool (gun) as the extended part of subjects'

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virtual arms, (f) a 3PP sequence with a human avatar, (g) a 3PP sequence with a robot avatar closer to the viewpoint of the subjects, and lastly (h) a 3PP sequence with a robot avatar farther from the viewpoint of the subjects. Heat maps and gaze plots were obtained for each sequence with the eye-tracking data, compared with each sequence's overall frequency of ranges of saccades and fixation for all of the subjects.

In this experiment, we observed the changes in the scope of visual perception in 3D navigation with respect to the perspectives and peripheral spaces, or namely peripersonal space [3], of the avatars. If a sequence had 1PP, where the users navigated without an avatar, the scope of visual perception were relatively large; the gaze plots were dispersed and displayed the arbitrary saccadic movements that seemed to scan the whole 3D environment. If a sequence had 3PP, however, the scopes of visual perception were relatively small, concentrated to both on the avatars' position and the peripheral space.

PERIPERSONAL SPACE AS A CONTEXTUAL CUE

There are two types of mechanisms involved in controlling the scope of visual perception: bottom-up process is driven by the perceived stimuli and top-down process is caused by the demands of attention [6]. Feedbacks from the two mechanisms are used to determine where to give more attention selectively, in order to economically utilize the limited cognitive ability. Although salient features often capture attentions (bottom-up process), people are prone to focus more on the task-relevant features (top-down process) to increase computational advantages [7]. The contextual cues from the components of 3D virtual environments such as spaces, objects, and events give hints about where those task-relevant features may be and help the users narrow down the scope of visual perception within perceptually manageable area [1].

In the 3D navigation experiment, the avatars seemed to works as contextual cues as well. As the avatars somehow displayed strong visual saliencies, the avatars themselves attracted the subjects' attentions at first, but once the subjects became familiar to the presence of the avatars, subjects seemed to use the avatars as contextual cues. Using the position of the avatars as a frame of reference, the subjects navigated the virtual environments focusing on the avatars' peripersonal spaces where the interaction between the avatars and the environments are possible. On the other hand, subjects tended to ignore the visual stimuli outside of the avatars' peripersonal spaces in which the avatars cannot interact, thereby irrelevant informational space. In case of 1PP with extended part of the avatar or tool shown, gaze points displayed capricious saccadic movements similar to the saccades of 1PP with some constraint. However, the extended part of the avatar in 1PP rather worked as a visual barrier or a contextual cue that limited the subjects' scope of visual perception and redirected the subjects' attention to the peripheral space of the extended part.

CONCLUSION AND FUTURE WORK

In this paper we proposed that the different perspectives and peripersonal spaces of avatars help users to adjust their scopes of the visual perception within 3D environments. Thus, it would be possible to effectively manipulate the perceptual scope of users by adjusting the presence and locations of avatars in 3D virtual space. This can be useful in designing 3D virtual space with particular purposes in applications such as a situation where users search for the nearest target from an avatar or work on a certain task with distractions from the background. For instance, when it is required to narrow the perceptual area to unburden users' cognitive load, it would be helpful to use 3PP with an avatar. And if it is required to navigate the environment without constraint, it would be better to use 1PP, though the scope of the perceptual area can be limited by using a pointing device (gun in our case) in 1PP as well. In our future study we will develop a personalized user interface system that helps adjust and predict the users' attention scopes in virtual space for educational purpose.

ACKNOWLEDGMENTS

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Abstract

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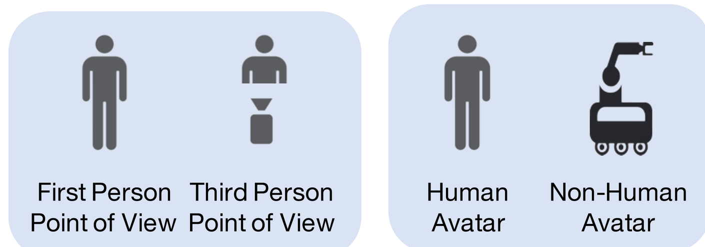
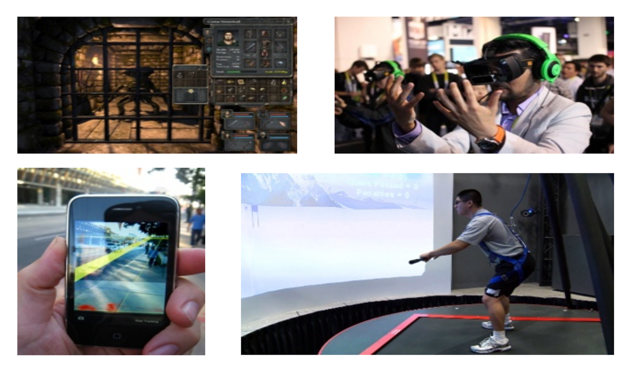
Study Design

Types of Avatar in 3D Virtual Space



3D Virtual Space Applications



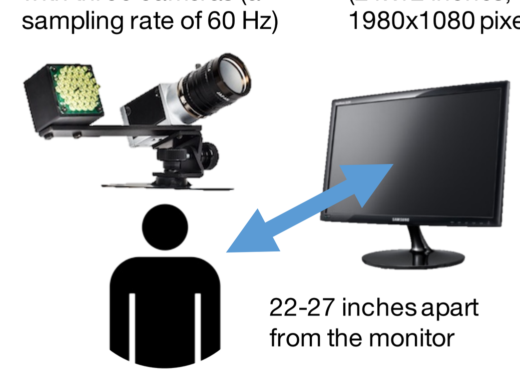
Participants

2 Males and 3 Females

Experiment Environments

Smart Eye Pro 5.9 system with three cameras (a sampling rate of 60 Hz)

Computer Monitor (21x12 inches, 1980x1080 pixels)



Video Clips

Set 1 (5 seconds) and Set 2 (25 seconds) with a frame rate of 24 Hz

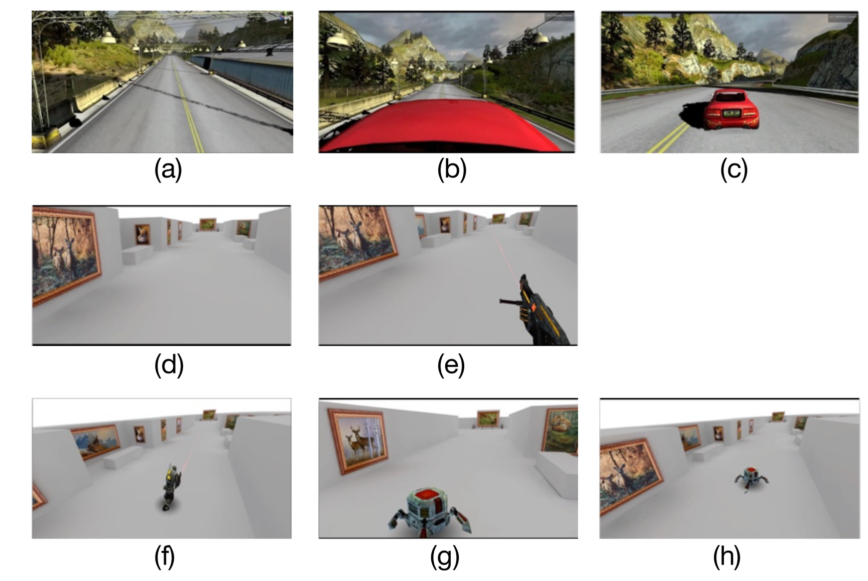


Figure 1. Two sets of 3D environments, a road and an art gallery, in both first-person (1PP) and third-person (3PP) perspectives.

Results

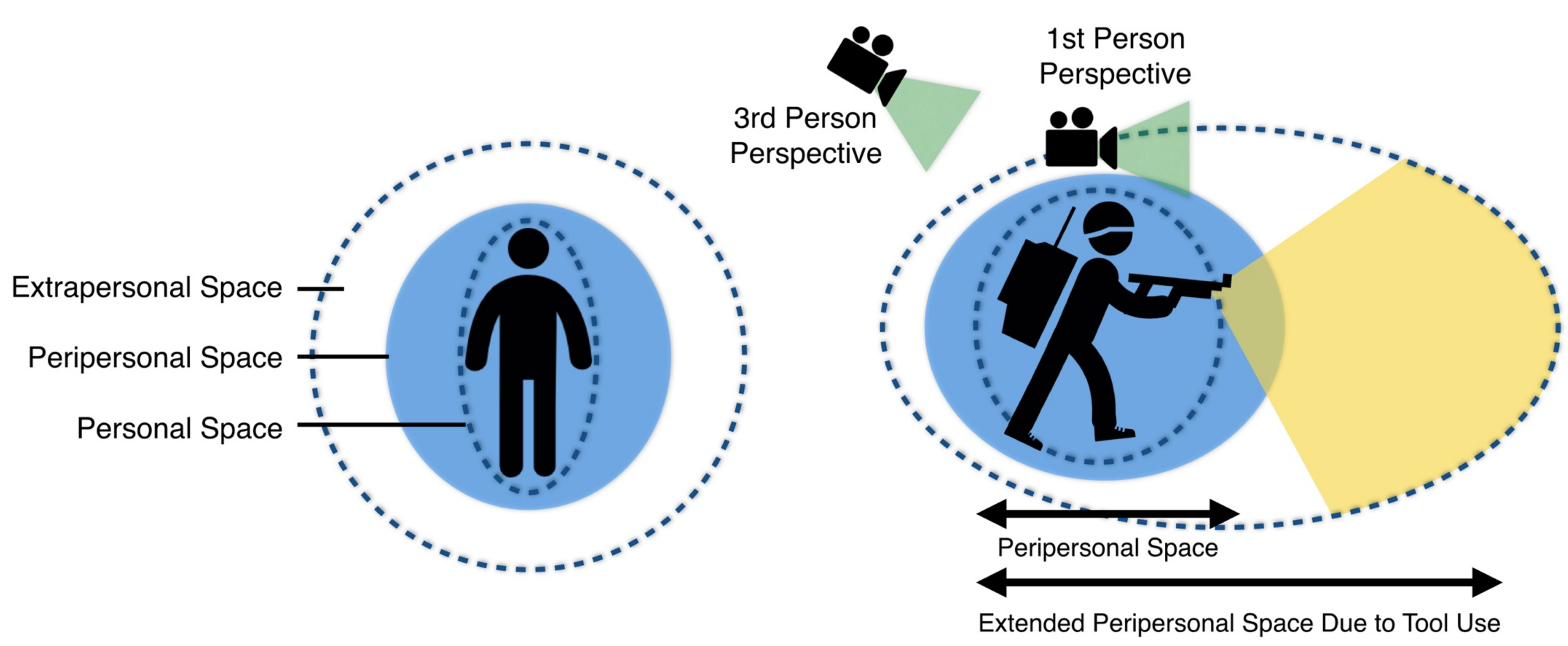


Figure 2. Body Space of Human and Peripersonal Space of an Avatar

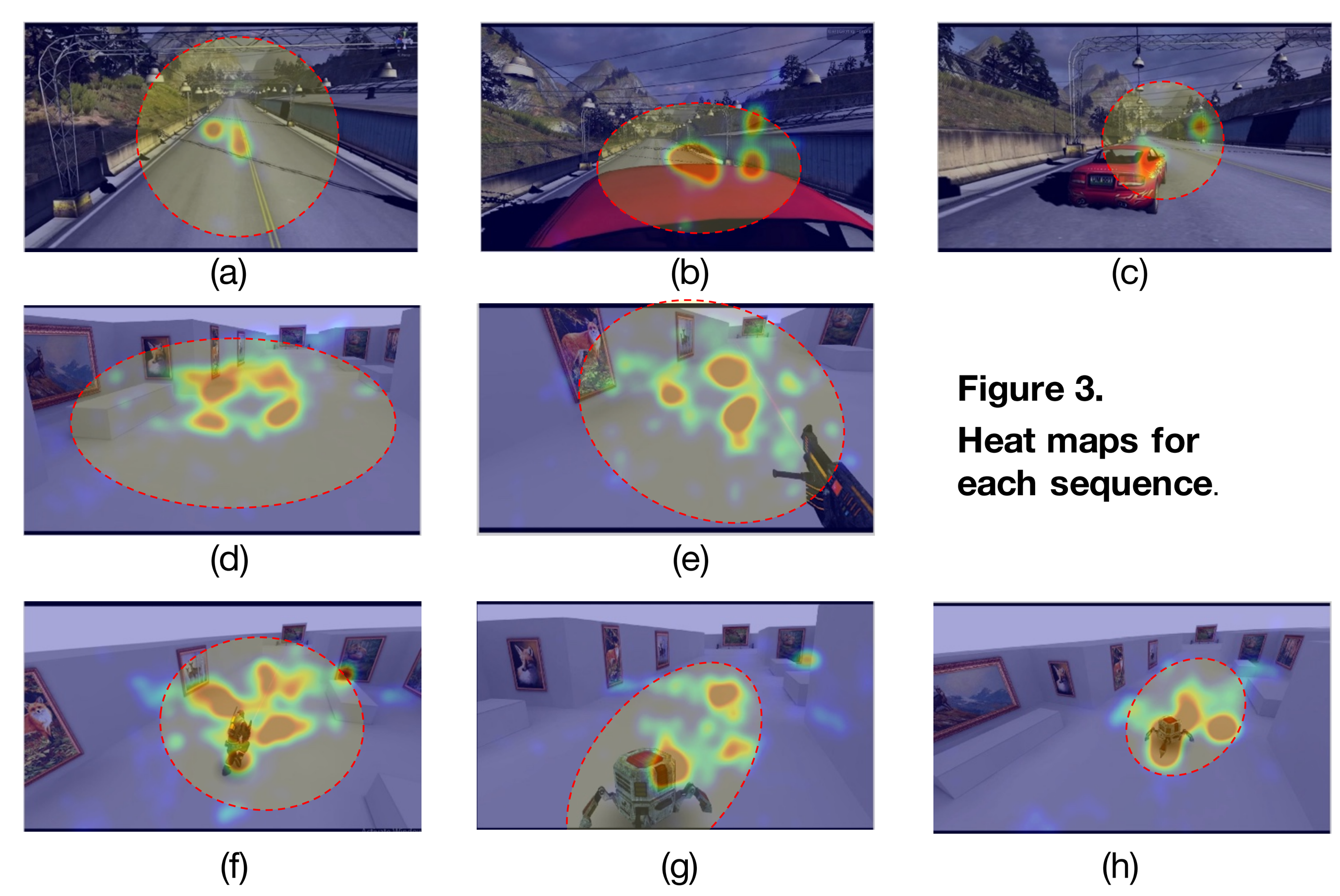


Figure 3. Heat maps for each sequence.

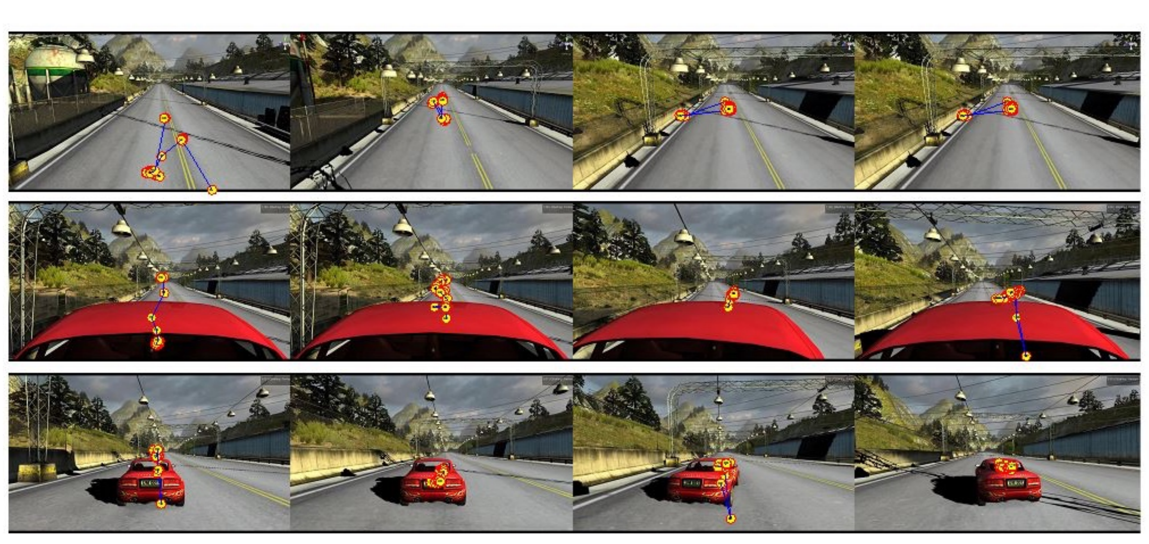


Figure 4. Gaze plots for Set 1: (a)PP1 without avatar, (b)PP3 car-near, (c)PPv3 car-far

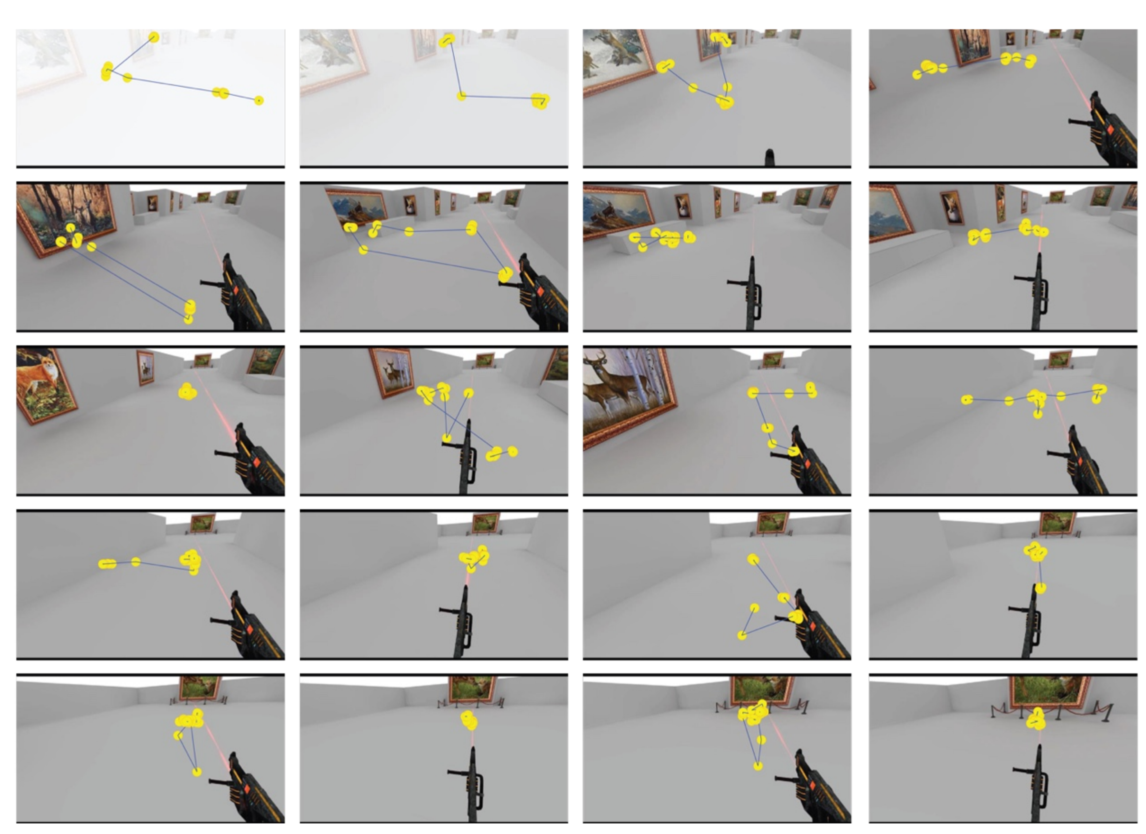


Figure 6. Gaze plots for Set 2: (e)PP1 with avatar

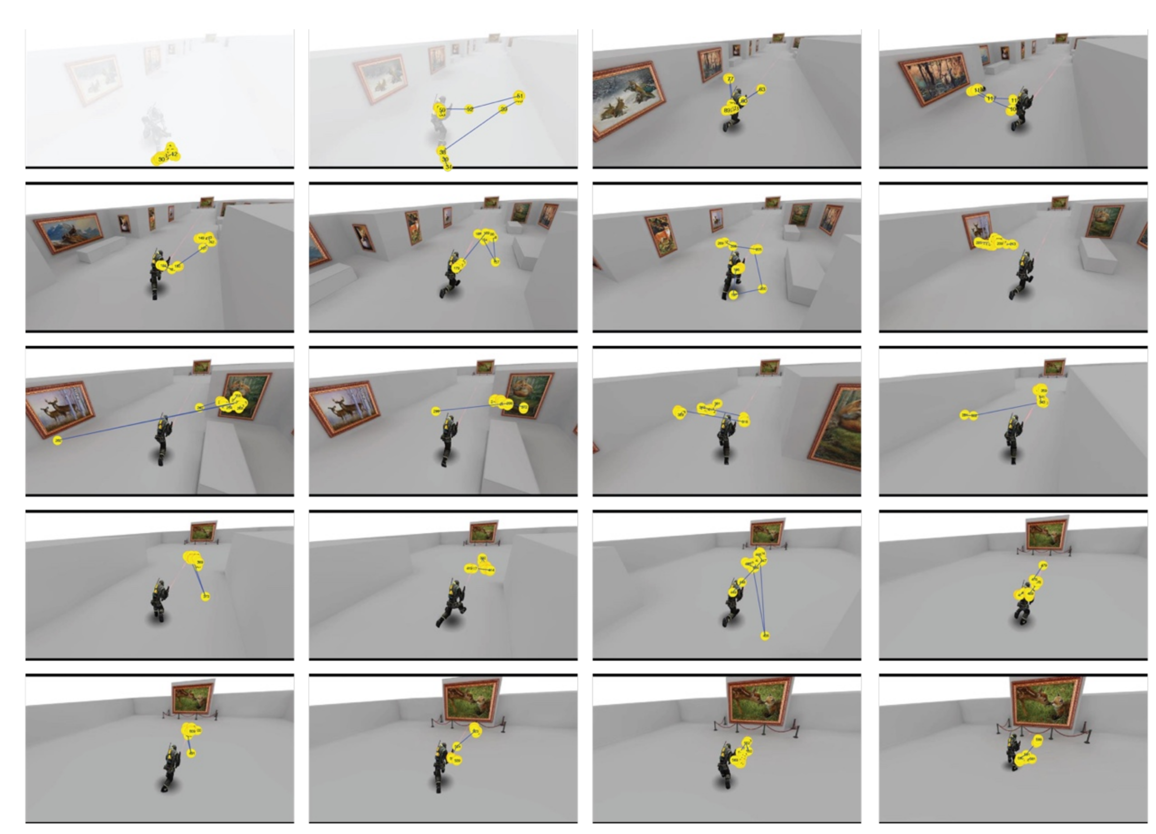


Figure 8. Gaze plots for Set 2: (f)PP3 human-far

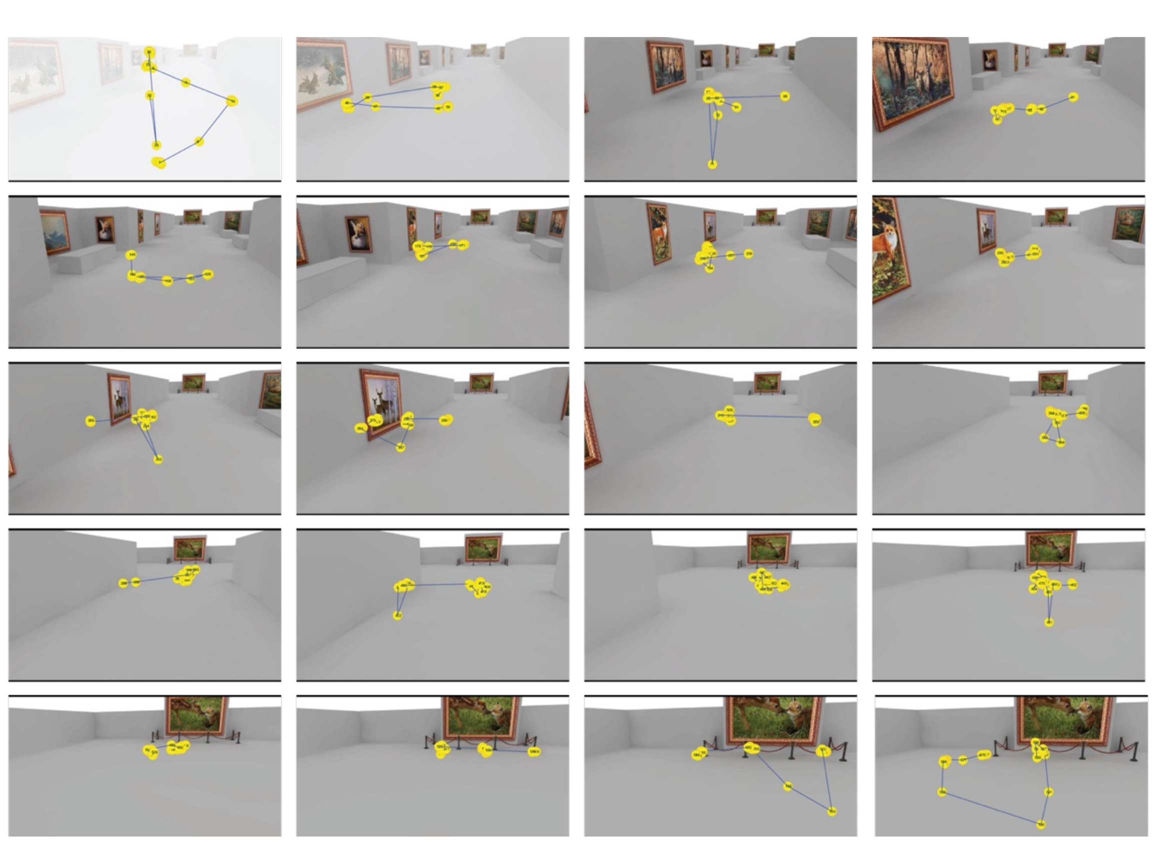


Figure 5. Gaze plots for Set 2: (d)PP1 without avatar

Figure 7. Gaze plots for Set 2: (g)PP3 robot-near

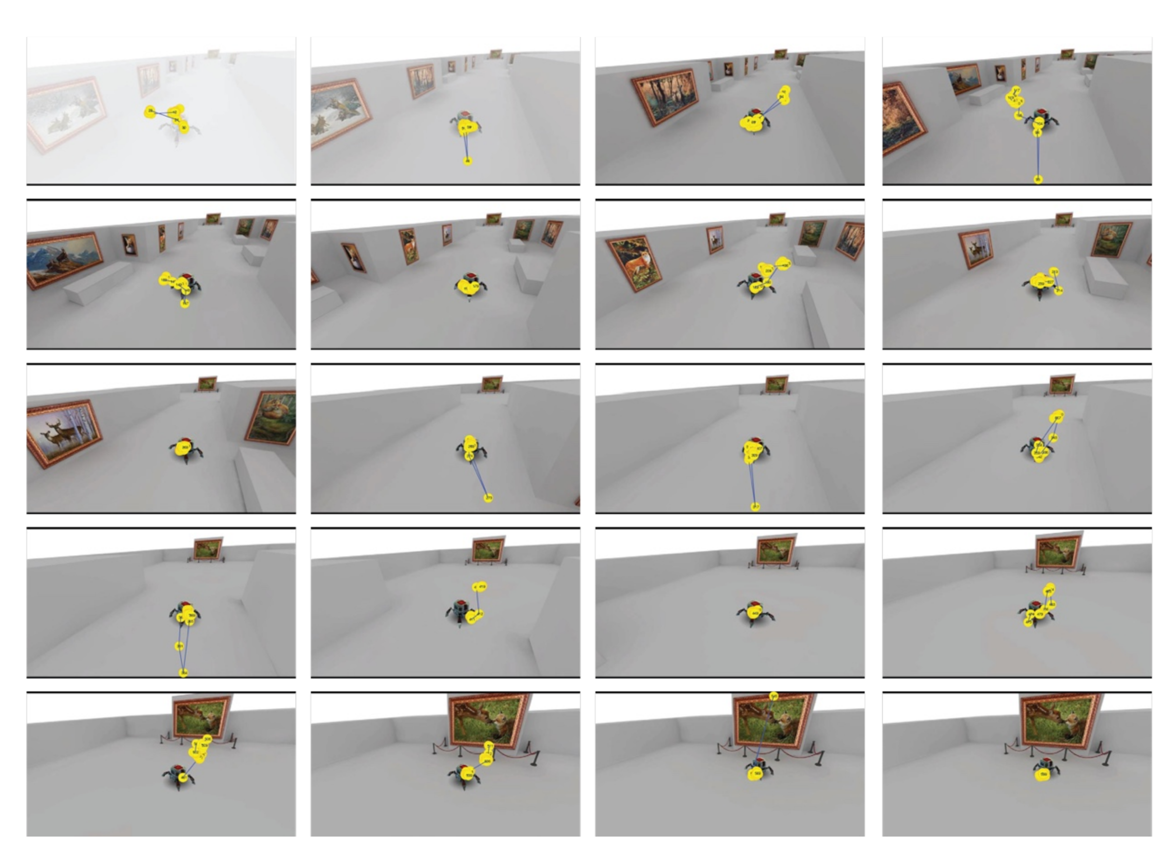


Figure 9. Gaze plots for Set 2: (h)PP3 robot-far

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