Quality of Experience (QoE) Evaluation of Locomotion Methods on Desktop Virtual Reality: Comfort, Effort and Enjoyment

ZHENJIE ZHAO, Nanjing University of Information Science and Technology
FENG HAN, Hong Kong University of Science and Technology
XIAOJUAN MA, Hong Kong University of Science and Technology

Virtual reality (VR) has become popular for such remote activities as virtual conferences and education owing to the COVID-19. While wearing a head-mounted display (HMD) can immerse users in a 3D environment, operating a desktop setting where users have a mouse and keyboard at their disposal, *i.e.*, desktop VR, is more accessible and has a lower barrier to use. One of the crucial components of desktop VR is how to explore a virtual environment. In a desktop setting, there are generally three options of navigation: 1) teleportation that moves a character instantaneously via a mouse click, 2) keyboard control that manually controls the movement of a character, and 3) auto-walking that moves a character around automatically. Although the three methods are designed with their own benefits, from the perspective of users' perception, there is still a lack of systematic investigation on their quality of experience (QoE). In this position paper, we conducted a between-subject study with 36 participants to evaluate the three methods based on comfort, effort, and enjoyment. Compared with previous evaluations, we focus more on users' subjective feelings on navigating in an experience-oriented visit to a desktop VR space. Our study results provide design suggestions for navigation on desktop VR.

CCS Concepts: • **Human-centered computing** → *Human computer interaction (HCI).*

Additional Key Words and Phrases: quality of experience, desktop VR, locomotion, self-reports, social VR

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1 INTRODUCTION AND RELATED WORKS

Owing to the COVID-19, many activities are organized online, such as virtual tours [5] and remote conferences [16]. Desktop virtual reality (VR) provides an accessible environment for people to interact with each other and enjoy a virtual space [5, 11, 16]. Compared to head-mounted display (HMD)-based VR experiences, desktop-based platforms, although not as immersive as HMD, has a lower barrier for users because it requires no extra setup, exploits familiar controls (*i.e.*, keyboard and mouse) and arrangement (*i.e.*, sitting in front of a screen), grants convenient access to other files on the computer, and may impose less discomfort and effort on users over prolonged periods of time [17, 18].

Navigation is imperative to most 3D virtual experiences. Whether it is to find their way from one exhibit to another in a virtual museum visit or from one lecture hall to another during a virtual conference coffee break, users need a locomotion method to direct their avatars' movement in space. Existing desktop VR mainly adopts three methods [1, 7]:

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Z. Zhao is with the Department of Computer Science and Technology, Nanjing University of Information Science and Technology, Nanjing, Jiangsu Province, 210044, China (e-mail: zzhaoao@nuist.edu.cn).

F. Han is with the Department of Computer Science and Engineering, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong SAR, China (email: fhanab@connect.ust.hk).

X. Ma is with the Department of Computer Science and Engineering, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong SAR, China (email: mxj@cse.ust.hk).

1) continuous free movement of a virtual character steered by manually pressing the W, A, S and D keys on a normal keyboard (denoted as WASD); 2) discrete character teleporting by selecting and jumping to a destination point in space with a mouse click; 3) auto-walking by simulating the experience of tourists taking a golf cart kind of ride in a park.

Given that navigation in desktop supported activities are often experience-oriented, *i.e.*, exploring the virtual environment in a leisurely and casual way to enjoy the scene or to socialize with others [16], it is critial to evaluate Quality of Experience (QoE) from the perspective of users' perception. Different from previous works on operating 3D software in a desktop setting that emphasize on effeciency of accomplishing certain tasks [3, 4, 9, 10, 13, 19], we focus on a social setting and consider subjective feelings of comfort, effort, and enjoyment as the metrics [6, 12, 14, 15, 20].

2 QOE EVALUATION AND RESULTS

We applied Mozilla Hubs [11] as the study platform which already has teleportation and WASD embedded. To enable auto-walking, we first planned a path with intermediate stops between a start and an end point to minimize collision with static objects, and then used the easing method [1] to control the avatar speed for a natural auto-walking experience. With all three methods in place, we carried out a between-subject study with 36 participants. Participants need to take a self-tour in a virtual campus with stops at given landmarks and take photos along the way. We conducted our experiment remotely without face-to-face interaction with participants. We consider users' perceived level of comfort with *Simulator Sickness Questionnaire* (SSQ) scores [8], amount of effort with modified questions from the NASA Task Load Index [2], and extent of pleasure with five self-created questions, including enjoyment levels on *1) moving from the start to the end; 2) the scenery along the way; 3) taking photos; 4) walking; 5) overall subjective feeling.*

Preliminary Results. We did not find statistical significance with the relatively small sample size and uncontrolled environment. However, there are still preliminary results that yield interesting design considerations. In particular, for comfort, people feel that auto-walking that needs less workload has better navigation experiences than WASD and teleportation in terms of SSQ scores (average nausea score: teleportation - 11.1, WASD - 18.3, auto-walking - 0; average oculomotor score: teleportation - 6.3, WASD - 12, auto-walking - 0.6; average disorientation score: teleportation - 16.2, WASD - 19.7, auto-walking - 0; total average score: teleportation - 11.8, WASD - 13.7, auto-walking - 1.6). For workload, we find that WASD introduces highest workload on mental demand, time demand, and performance, while teleportation leads to highest workload on physical demand, *e.g.*, turning, controlling, activating, *etc.* This indicates that although manually navigation with WASD takes more effort mentally, which may result in longer time and lower performance, teleportation without flexibility will bring about more physical efforts when users need to find their ways through winding places or places with lots of obstacles. It is critical to balance workload and flexibility. For enjoyment, auto-walking generally has higher and more stable enjoyable experiences. We then used thematic analysis [2] to analyze our interview transcripts in an inductive way. In general, we found that 1) athough teleportation can take users to destinations quickly, the limited user control on distance moving and direction facing make it less favorable; 2) WASD movement is intuitive to learn and control, especially for novice users, but its workload prevents people from applying it frequently and it is also less like a real walking experience, *e.g.*, WASD cannot adjust moving speed arbitrarily, 3) auto-walking balances comfort, effort, and enjoyment well, but people want it to be more flexible to control.

[1] https://developers.google.com/web/fundamentals/design-and-ux/animations/the-basics-of-easing
[2] https://humansystems.arc.nasa.gov/groups/TLX/downloads/TLXScale.pdf

3 CONCLUSION

The purpose of this position paper is to gain a deeper understanding of locomotion QoE in a desktop setting. To achieve that, we evaluated three methods – teleportation, WASD, and auto-walking – using the Mozilla Hubs platform through a between-subject study, and asked them to self-report subjective feelings in terms of comfort, effort, and enjoyment. Our preliminary analysis provide design considerations when designing a navigation method on desktop VR.

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