Virtual Reality as a Tool for Measuring Spatial Tendencies in Urban Experience

Burcu Nimet Dumlu[1]
[1]*Fatih Sultan Mehmet Vakıf University and Istanbul Technical University*
[1]*bndumlu@fsm.edu.tr*

Virtual reality (VR) enables the controlled acquisition of physical reality into the virtual environment. The virtual built environment stimulates people as physical urban experiences. Room-scale experience allows wandering around the urban space. The purpose of this study is to understand VR as a tool for measuring spatial tendencies of the individual through distance structuring (proxemics) in the virtual environment. According to the concept of proxemics, individuals interact with the built environment and people through personal, social, and public distances. The study provided a virtual space that was designed as a streetscape with a road and buildings along the way both sides. Users were immersed in the VR model for 10 minutes through navigating on the chosen route and recorded in the video. The objective was understanding how the architectural elements are related to proxemics tendencies. This study describes VR as a tool for understanding user tendencies through user spatial behavior.

Keywords: *Virtual Reality, Virtual Space, Proxemics, HTC Vive*

INTRODUCTION

Virtual reality (VR) is a new media platform in which physical reality reconstruction through the computer (also defined as simulation). Baudrillard (2011) explains that simulation is a hyperreality that reality is reproduced through models. With the modern age, the human becomes a spectator who is the one that builds his/her reality, and this helps him develop methods of understanding his world. Bolt (2013) illustrated modern humans as becoming the decisive center of our physical reality with technology. The human is in physical reality and forms the image of the world through the relationship of the world with him/herself. This spectator human considered to be the one who provided his/her spatial movements in physical reality. The spatial tendencies of the spectator human existed within the built environment, so s/he maintained this situation in the virtual reality medium. In this study, the concept of a virtual spectator means the VR user. This user shows spatial tendencies associated with being-in-the-virtual-world (which is defined by Richard Coyne [1994]) in the virtual space. Coyne (1994) explains, "within our experience of being in the world, there is a pragmatic understanding of proximity or closeness, and this closeness precedes any notion of measurable distance". In this context, the user being aware of the virtual space in which s/he was immersed in is the one who materializes spatial proximities according to their tendencies.

The three-dimensional possibilities of virtual reality enable the user to be immersed in media. Human is physically present in physical reality with bilateral vision (Sussman & Hollander, 2015). Virtual reality head-mounted display (VR HMD) brings the phenomenon of bilateral vision in the physical environment to the virtual environment with stereoscopic vision. Whyte (2002) explains that VR allows users can experience the virtual world from a real-world point of view which is viewer-centered (egocentric) and also if there is a virtual representation of the human body in VR (avatar), users can see their positions in the virtual environment.

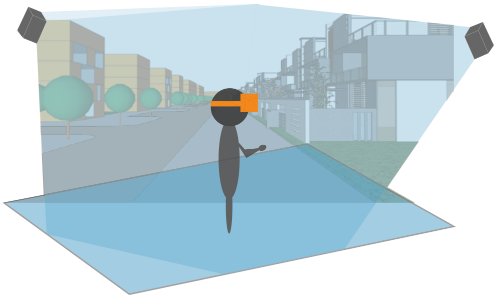


Figure 1
HTC Vive Head Mounted Display (HMD) room-scale installation

This provides experiencing the physical built environment inside a virtual medium. Also, VR creates a controlled environment and gives the opportunity to use all the variables according to the research aim to investigate. Yaremych et. al. (2019) summarizes that VR let researchers manipulate all variables as real-world circumstances and also an opportunity to ecological validity. The virtual environment stimulates users in a spatial context, such as a physically constructed environment. Spatial tendencies occur within the concept of presence and evaluated in the context of virtual-presence. The concept of virtual presence comes from science fiction, science fiction writers have described conceptual versions of virtual reality (VR) and telepresence for decades (Gibson, 1984). Flach and Holden (1998) explain that Gibson's understanding of virtual presence based on the relationship between perception and action. They stated that "the reality of VR experience is grounded in action" (Flach and Holden, 1998). According to the literature, VR is suitable for use as a controlled experimentation environment, this study gets its basis from these researches.

The HTC Vive virtual reality headset installed in a defined space called room-scale (see figure 1). The 360-degree vision (6DoF - six degrees of freedom) and spatial navigation possibilities provided by the glasses are similar to reality while providing a measurable environment in the virtual space. Therefore, virtual space becomes a tool to measure physical behaviors and orientations. The research by Franz et al. (2005) revealed that VR simulations are beneficial for optimized empirical methods in architectural research. Their findings showed that VR is a useful tool for understanding emotional experiences based on empirical researches in the physical environment (Franz et. al, 2005).

In this study, urban space was modeled and uploaded to VR HMD, so users were able to experience this model through glasses. After that, they participated the urban model experimentation. During these experiences, their behaviors recorded in video to measure their distance structuring tendencies in VR experience. 5 users participated in this experimentation and their behavioral data have been collected through videos and analyzed. The scope of the research is understanding the proxemics behaviors while interacting virtual urban environment.

PROXEMICS BEHAVIOR

The proxemics behavior defined by cultural anthropologist Edward Hall in 1963 as a valuable term for understanding people who interact with each other and with their environment, "the organization of spaces in houses and buildings, and ultimately the settlement of (cities)." (Hall,1963). As he defined that unlike most of the traditional subject of anthropological observation, proxemic patterns once learned are largely excluded from conscious awareness and therefore should be explored without the need to explore the conscious minds of one's subjects (Hall, 1963).

Hall (1963) cited that Grosser (1951) described how and why portraits in the western world were painted at specific distances, with reference only to intimate, personal and social distances. An artist used the distances were when placing elements in a picture's composition designed to transmit certain characteristics of personality as well as to scan all other features, and Grosser fixed these observations to feet and inches (Hall, 1963). Hall studied how people unconsciously construct the distance between each other in carrying out daily operations, space organization and urban settlement (Hall, 1963) (see figure 3).

This research is designed in the context of measuring the distance structuring tendencies of the virtual individual. The concept of proxemic is defined as 1 m personal distance, 4 m social distance, and 7 m public distance (Sussman & Hollander, 2015) (see figure 2). Since these distances can vary in every culture and geography, they will be measured conceptually (personal, social, and public) and not quantified as numbers. Witmer and Kline (1998) conducted research on can users experience virtual distances as real-world distances? They achieved that virtual environments did not include more reference points to perceive the distances as the real-world distances (Witmer and Kline, 1998).

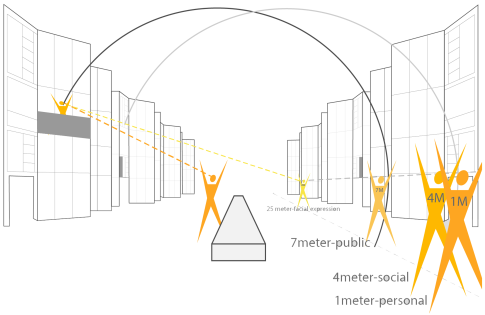


Figure 2
Proxemics Diagram

Therefore, virtual built environments need to be developed based on physically built environments in detail. Popp et al. (2004) also investigate user distance perception in VR by using different tools such as treadmills and seating on a chair, they stated that both groups had underestimated the distances. Walking through teleport can be counted as causing the same effect on distances, so this study experimentation can be conducted by walking, teleporting, or seating on a chair. These variables have no negative effect on distance configurations in VR. Sanz et. al. (2015) states that users behaved the same in both physical and virtual environments when they faced an obstacle object such as a wall or virtual wall. Slater et al. (2016) summarize that VR is a useful tool to understand social interactions and fundamental social behaviors.

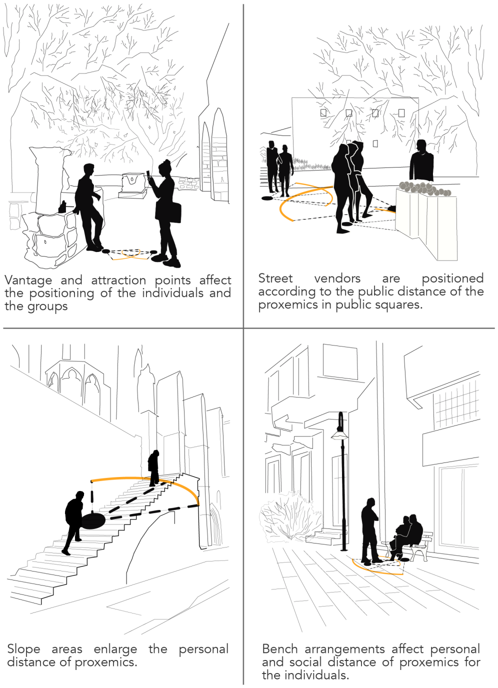


Figure 3
Proxemics in Built Environment (Analysis from Minding the City/Famagusta Workshop by Tülay Karakaş, Burcu Nimet Dumlu)

There are proxemics researches in VR and their focus is social interactions with avatars, robots, virtual agents, and other virtual interactive human-like elements. One of the studies in which distance configurations investigated in the proxemic context was reevaluated in virtual environments, and experiments conducted by the virtual individual in the virtual environment are created through the avatar explores the distance configurations (Hecht et al., 2019). Their findings revealed that if the users were able to see their body as an avatar, immersion feeling became stronger (Hecht et al., 2019). Another research from Bailenson et. al. (2003) showed that participants have behaved respectfully as the personal distance to the characters inside the virtual environment. Rodriguez et al. (2019) implemented computerized agents to their virtual reality model and they aimed to understand user proxemics behavior when they met these agents In VR. Their purpose is to understand the proxemics of users when they are around virtual agents. The literature has a gap in the user's proxemics behavior with the interaction of the built environment.

This research defined the VR environment as a tool to measure the spatial behavior of the user through the controlled structure of the VR. The concept of proxemics determined for the measurement definition for this. In this study, the conceptual framework built on proxemics (distance studies on built environment), presence and virtual being studies (see figure 4). The user behaviors and reactions revealed the factors and effects in the VR environment, so the knowledge construction on distance structuring became possible with this study.

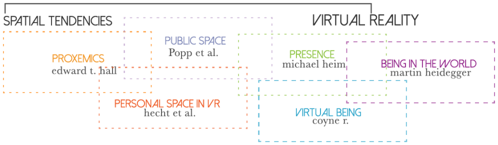


Figure 4 Concepts and Literature

The controlled structure of the virtual space provided the opportunity to record and analyze the factors. The study aimed to make the factors and stimuli affecting spatial tendencies understandable through behavior measurement and observation in the virtual environment.

METHODOLOGY

The research procedure was carried out through a 3-stage experiment. In the first phase, a three-dimensional model representing the physical environment was transferred to the virtual reality environment via VRSketch (Google Sketchup modeling program virtual reality plugin [2]).

In the second phase, the five users experienced the urban VR for 3 minutes and this was repeated 3 times with 1-day intervals. In order for the user to prevent the effects of the first encounter with the tool, each user experienced the VR space 3 times to grasp the tool and the environment. In the first experience, it was envisaged that the user normalizes the relationship established with the VR tool, so after the first experience, the user developed familiarity with the VR tool. For each of the 5 people, the average duration of VR tool engagement is examined in terms of how the differences and similarities occur in these processes. In the second experience, it was aimed to comprehend the virtual urban environment. The third experience aimed to measure the distance structuring of virtual individuals (see figure 5). The proxemics tendencies of the virtual individual had been examined and the issue of identifying what is happening if there is a relationship or contradiction between the distance structuring of the 5 individuals has also been evaluated.

The third phase of this experiment was the analysis of spatial tendencies in the proxemics context. During the analysis, standpoints were determined through the behavior of the virtual individual recorded in video format during the experience. Glance-points (where users looked at) and Standpoints (where users standstill) were detected to all 3 experiences for each person. The data of the three individual experiences of 5 people and their relationship and contradictions were determined. The analysis data included questionnaire results of the users.

The reactions/interactions of the users were observed and traces of behavior were identified to clarify proxemic tendencies. These traces have been created in the virtual space by means of circulation paths that can be drawn by instant identification of the user's coordinates. In addition, data such as points at which users direct their glance (viewpoints), waiting times at these points (standing points) were decoded through videos recorded during the experience (see figure 7).

Then, interviews were conducted and questions about the experience were collected to reveal data that could be associated with feelings and traces. The interview questions were compiled in order to reveal the reasons for glance-points and stand-points. Parts of the videos during the virtual experience were shown and asked to explain why. It was aimed to understand the relationship between architectural elements and the moments of glance and stand. The questions were designed to provide more information about individual virtual experiences. Traces and interview data were evaluated together. This study questioned how virtual reality can be defined as a tool for measuring proxemic tendencies in virtual space.

VIRTUAL REALITY STUDY

Spatial tendencies of the users were investigated in the context of proxemic with 5 people in the virtual reality environment. They experienced VR urban space 3 different times through HTC Vive HMD [1]. Every user experienced VR space 3 times (1-day intervals) for 3 minutes. The design of the virtual built environment was a mimicry of a physical street. The rendering level of the model was defined as the limitation of the study. Their visual aspects were lower than reality, so the users were aware of being inside a virtual model based on the materials and low details.

The street included buildings on the left and right sides. The left side was constructed with only empty facades and low-poly trees. The right side had detailed facades with high-poly plants. Also, the right side has details in interiors which caused the curiosity of what is inside the spaces.

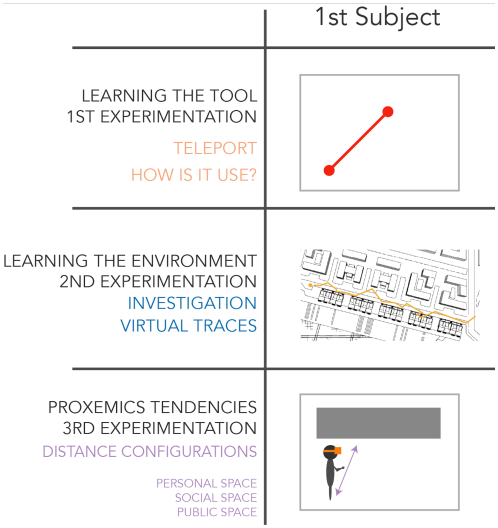
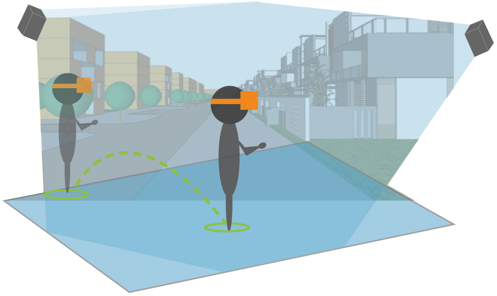
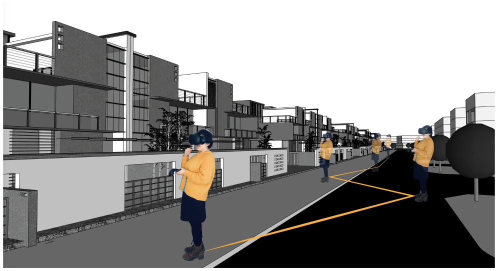


Figure 5
VR Analysis
Methodology

In the first experience, the users wore the VR HMD in order to develop familiarity. Firstly, they learned how navigation command works (Teleport [see figure 6]). They used the teleport command inside the urban model for 3 minutes. Comprehension of the command happened immediately for every user. They got used to command in 15-20 seconds. They had been accustomed to the tool at the same time. The users who discovered the navigation command, after realizing that the command can be irradiated to the points on the horizontal surfaces, were found to have approached such as climbing on the garden wall and looking from the balcony to examine the detailed facades.



After the navigation command became an oriented gesture, users can do it without focusing on triggers. This situation increased the feeling of walking in virtual environment. Users mentioned that teleportation feels like walking. They expressed that it was an exciting experience to be able to beam to horizontal planes and observe buildings from different points.



In the second experience, users tended to move around the entire map and wanted to finish wandering around at the end of model space. Repeated patterns caused monotone experience for all the users. They realized that all buildings, detailed ones and not-detailed ones, are repetitions of each other. The biggest similarities were the recognition of monotonous and attempting to enter the spaces, while the contradictions were that some of the users followed the roads and some of them tended to move through the spaces and all the open points on surfaces that they met.

In the third experience, it was observed that the users placed the details (such as the door number) at their personal distance and looked closely at them. They examined the places with having transparency (window, space, etc.). Users wanted to navigate to horizontal surfaces through the navigation and look at places in ways that could not be done in real life. They constructed different angles through leaning on the balconies, this provided different glance and standpoints. They tended to teleport on other side of the road when they aimed to perceive bigger model elements such as facades.

RESULTS

At the end of the three experiments, the analysis revealed that there are three types of results. The first type is verbal expressions about VR experience and virtual presence. The second type is user traces on virtual models with positional behaviors with the proxemics interpretation. The last type is the comparative analysis of the other two results.

For the first type, subjects expressed verbally that which points on the model is better for perceiving the street and the buildings. They stated that experiencing the virtual space through physically impossible angles and heights was the most exciting part of this study. "Hanging down from a balcony" without any danger of falling enriched the spatial experience for most of the subjects. This situation confirmed through the video recordings of the experimentations. The results revealed that the users tried different horizontal surfaces to navigate and looked around standing on that unusual surfaces such as the top of the garden wall or roofs. The VR HMD tool provided situations that cannot be happened in real life, so the perception of the urban space in VR from different angles triggered the user pleasure. They also stated that being-in-the-virtual-environment and teleporting around creates the feeling of walking. When the surface details increased, subjects tended to stand still and look at these surfaces. The right side of the model has detailed architectural elements, so they said that they tended to look inside these buildings and facades.

Figure 6
VR Navigation (Teleport)

Figure 7
VR Experimentation

Figure 8
The analyses of 5 users for 3 experimentation

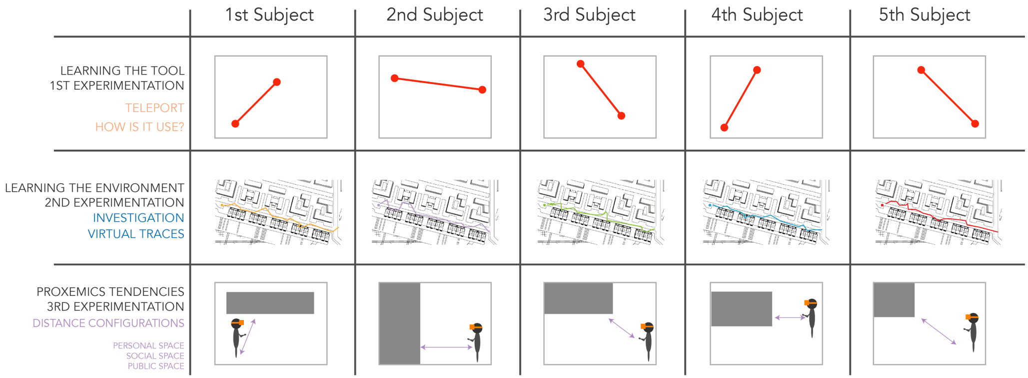


Figure 9
Chosen point of view for analyze

There is no danger for falling down during the virtual reality experience allowed different glance points through impossible positions (for physical reality). The common reaction of all users was to look at places from different angles and surfaces. The points that users wanted to establish proximity were the detailed points of the model (see figure 8).

The second type of results revealed that the user virtual traces in VR are consistent. The traces are categorized as standpoints and glance points. Standpoints are where the users stop teleporting and looked at around. Glance points are where they stop teleporting and stare at for a moment and then continue to teleport around. When users placed the elements closer to their personal spaces, their standing durations were increased (see figure 11). The analysis of the chosen point revealed that their attention and looking closely tendencies matched on the same points (see figure 11).

Their viewpoint choices were located with considering the video recordings from virtual experiments. On the other hand, they have structured their standpoint distances according to different aims. If they aimed to perceive the whole facade, they were teleported to a point on the opposite sidewalk and stayed at public distances. The movement never done by their head, they teleported to the public distance. Then, if the users aimed to stare at a large element such as a whole facade of the building or the upstairs windows, they positioned themselves on "the public distance" with this whole facade. The observations revealed that when the users tended to examine a small detail as a door number, their proxemics became personal distance. In the end, the horizontal planes such as the top of the garden walls triggered the users to create their social distance for these elements (see figure 9). All users virtual traces supported these findings (see figure 10).

The last type is the comparative analysis of the verbal statements and virtual traces. Videos, virtual traces, and user verbal expressions are totally consistent. The biggest similarity among the findings from all experiences was that all users tended to look to the left and right using the 6DoF feature in a total of 9 minutes of experience. The up-down head movements were quite low (see figure 11). Users tended to look at their right and left not up and down. This situation is validated with user statements and virtual traces.

CONCLUSION

As a result of this pilot study, the potential status of virtual space as a tool for measuring spatial tendencies was discussed and it was concluded that VR is a functional tool for understanding proxemics in urban space. Gibson's explanation of reality construction gets its basis on the action and immersed urban experience successful as a physical urban environment. Users tended to behave as the reality in VR.

Standing points were similar for 5 of the users. They stand and looked at the details more than larger elements. Their behavioral patterns are coherent for five users. Also, their descriptions and expressions about experience have lots of similarities. These consistencies showed that proxemic tendencies are visible in VR (in the study public and personal distances identified.).

In the continuation of these studies, the sense of reality level for the materials and modeling details will be increased. Then, the modeling details considered at different levels and the various architectural/urban elements (street elements) will be adapted to this model. The future study will be conducted to understand how users structured their distance configurations with these urban elements (such as streetlights, bollards or benches). Using increased model detail for creating a sense of real urban space model with street elements establishes an assist for measuring better. Distance configurations will reveal human-space relations according to their spatial tendencies based on proxemics behavior.

The VR provided a controlled change of parameters and the opportunity to measure the effects of all virtual urban elements such as roadside borders, building facades, shop facades, cars, humans, and the variety of urban components. This situation creates the possibility of understanding human spatial tendencies better than any other digital platform. Also, the virtual reality environment becomes an advantageous tool for the integration of instruments used in the neuroscience field (such as EEG [Electroencephalography], ECG [Electrocardiography], and GSR [Galvanic Skin Response], motion data). It is possible to define emotional states of the

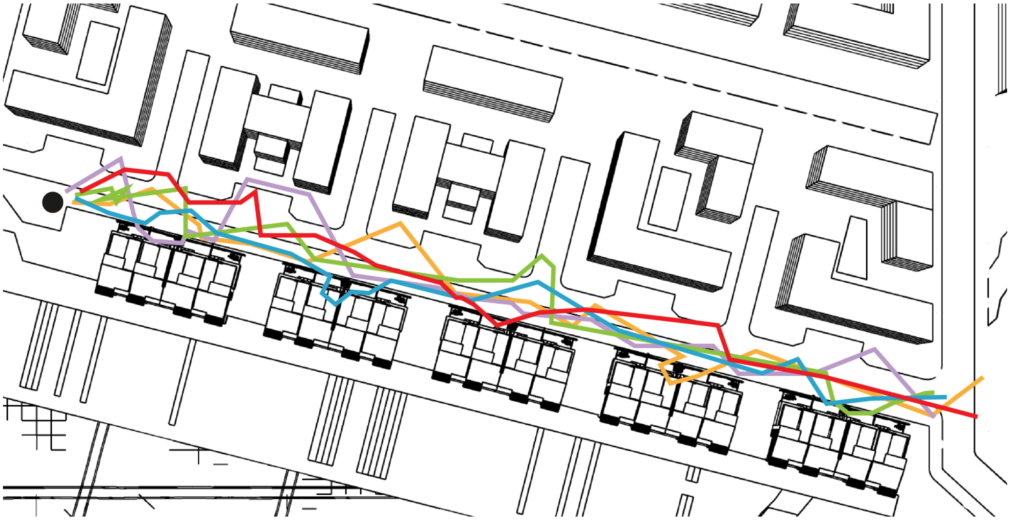


Figure 10
The traces of the 5 users

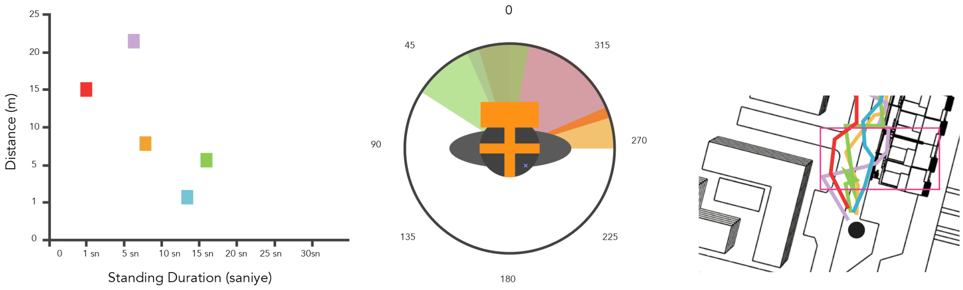


Figure 11
Chosen point to analyze for 5 users

user behaviors in response to the collected signals. Human emotional states and reactions can be interpreted through EEG, ECG, and GSR signals. According to current experiments, the VR environment can stimulate users as a physically built environment, and these neuroscientific tools explain the virtual urban experiences by using emotional states. Therefore, future studies will be conducted with neuroscientific tools in the VR environment in order to understand human tendencies.

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