

Emotional-Driven Gameplay: Exploring Gesture-Based Interactions in XR Environments

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Abstract: This research dives into the fascinating world of virtual reality (VR) and how gestures can evoke a sense of human-like behaviour, enriching emotional and immersive experiences while fostering empathy. By analysing both subtle and broad body language, the goal is to create a system where gestures can shape our physical and emotional reactions, allowing for more natural and intuitive non-verbal communication. Ultimately, the study aims to enhance empathy through expressive virtual interactions, helping to connect the digital realm with our physical presence.

Keywords: Virtual reality, Hand gestures, Emotional responses, Empathy building, Spatial environment, Game technologies

1. Introduction

Virtual reality (VR) has completely changed the way we interact online by creating immersive environments that really pull users in. This study takes a closer look at how spatial design and nonverbal communication, especially hand gestures, affect user experiences in VR.

By utilizing the Meta Quest 3 VR headset's built-in camera for gesture recognition and a Rokoko motion capture suit to give the character better feedback gesture like human behaviour, the research dives into how familiar gestures can evoke emotions in various virtual settings. Nonverbal communication, like body language and hand gestures, is essential for creating natural and intuitive interactions in digital spaces.

Previous research on nonverbal emotional expression and gesture-based human-computer dialogue lays a solid groundwork for understanding how movement impacts user engagement. This study zeroes in on how different spatial environments shape these interactions, particularly in both enclosed and open areas. The findings indicate that personal interactions in enclosed spaces tend to elicit stronger emotional responses because they offer a controlled, distraction free environment. In contrast to another special environment designed with more characters and elements introduce outside stimuli that can muddle gesture-based communication. While open spaces, allow for more freedom of engagement, the absence of clear focal points might result in less deliberate gestures.

These design principles resonate with earlier research that emphasizes how spatial distance can influence emotional reactions. By exploring these dynamics, this study underscores the potential of VR and motion capture technologies to create immersive, emotionally engaging virtual interactions. The insights gained here could pave the way for advancements in educational applications, interactive storytelling, and the future of gesture-driven VR experiences.

Overall, the study shows the exciting potential of VR and motion capture technologies in crafting immersive, gesture-driven experiences that push the boundaries of educational and interactive design in virtual reality.

2. Literature Survey

Recent studies have extensively explored VR and nonverbal communication. Research has demonstrated the importance of nonverbal expressions in conveying positive emotions, highlighting how gestures and facial cues effectively communicate different emotional states [4]. This aligns with the use of hand gestures as controllers in VR environments, such as the Meta Quest, where natural movements enhance immersion and emotional connection.

A critical review on nonverbal communication in immersive VR examines how VR transmits nonverbal cues, such as gestures, gaze, and proxemics, which are crucial for presence and social interaction in virtual spaces [5]. This is particularly relevant for educational and training applications, such as scuba diving or space station simulations, where gestures serve as intuitive controls and communication tools.

Studies have also investigated VR as an interview technique, showcasing its potential to assess communication skills and emotional responses in con-trolled settings [6]. This method can further explore how spatial

environments and gestures impact emotional content, providing insights into human behavior and nonverbal communication.

The cognitive and communicative advantages of gestures have been highlighted, emphasizing their role in improving understanding and memory [7]. This has implications for using VR to assist individuals with autism or those learning sign language, as gestures help bridge the gap between verbal and nonverbal communication.

Much of the current VR research focuses on creating more natural and immersive user interfaces through motion capture and advanced computing techniques that replicate natural body movements and facial expressions [8]. Studies suggest that adding detailed gesture recognition and body language capture can significantly improve user engagement in visceral environments.

However, there are still some significant gaps in the area. While virtual reality (VR) is becoming more popular for educational purposes, many existing studies tend to focus on things like interacting mechanics, learning outcomes, and how effective gesture-based controls are. It hasn't been explored enough is how gestures contribute to emotional engagement in educational virtual reality experiences, especially in terms of how emotional responses are triggered and captured through nonverbal interactions. Most of the current systems prioritize usability and understanding, but they fall short when it comes to systematically capturing and analyzing the emotional reactions tied to gesture-driven interactions.[9] This presents a valuable research opportunity: integrating emotional feedback mechanisms could really deepen engagement in educational virtual reality applications. By addressing this gap, we can gain a more comprehensive understanding of how gestures impact both learning and emotional connections in virtual environments.

3. Methodology

This study takes a mixed-method research approach to create and evaluate a gesture-based interaction system in virtual reality (VR).[1] By blending qualitative and quantitative methods, the goal is to deliver a thorough assessment of the system's architecture, gesture recognition accuracy, and interaction fidelity within virtual reality environments, specifically using the Meta Quest 3 framework and Unity's mixed reality development support.[7][8]

3.1 Research Design

The research follows a well-structured framework that merges technical validation, user experience analysis, and game design principles to evaluate gesture-driven interactions in VR. It employs three distinct methodological strategies [2][3]:

- **Embedded Design:** The focus was on assessing system performance. However, insights gained from real-time gesture responses were also integrated into the analysis to enhance the interaction framework, game design principles, and overall usability. This approach ensured that the technical aspects of gesture tracking were in sync with user behavior and emotional engagement.
- **Explanatory Sequential Design:** Initially, a quantitative analysis of gesture recognition accuracy and latency was conducted to establish a baseline for system performance. Next, qualitative assessments were carried out to explore interaction dynamics and user responses, ensuring that the findings were interpreted in context and directly linked to improvements in user experience. This sequence facilitated data-driven enhancements, fine tuning the system's responsiveness based on real user feedback.
- **Exploratory Sequential Design:** A preliminary qualitative review of gesture-driven VR interactions was performed. This helped inform early adjustments to recognition modeling and game design elements. Following these initial refinements, quantitative testing was conducted to validate the enhancements in interaction efficiency.

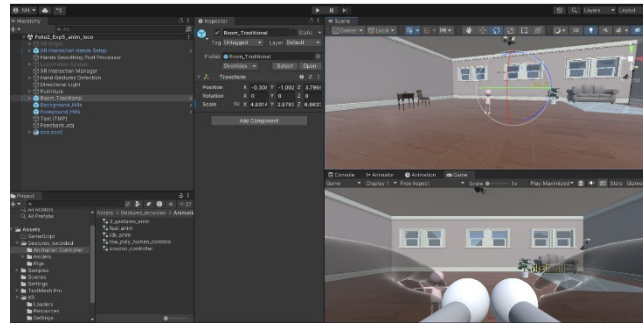


Figure 1: VR setup in unity

3.2 System Architecture and Gesture Processing

3.2.1 Gesture recognition pipeline

The system employed computer vision-based tracking and machine learning classification within the Meta framework to identify both macro- gestures and micro-gestures. Hand tracking data from the Meta Quest and a motion capture suit were processed in Unity engine. The mixed reality (XR) supported package was used to distinguish between static and dynamic gestures.

3.2.2 Environment and Interaction Modeling

The 3-dimensional environment to support virtual reality was crafted using Unity, dynamically adjusted to recognized gestures, triggering real-time changes in lighting, spatial audio, and object interactions. These enhancements created a more immersive experience for users.

4. Tools and Techniques

4.1 Important Considerations

The gesture recognizer supports static poses only, meaning dynamic gestures (e.g., swiping or throwing motions) are not recognized.

A Static Hand Gesture component was added to the scene, configured to reference Hand Shape or Hand Pose assets along with an XR Hand Tracking Events object that is supported by mixed-reality headset. This component triggers Unity Events upon detecting or ceasing a gesture.

4.2 Gesture Mapping and Emotional Correlation

The following custom gestures were designed and mapped to specific emotions:

- **High Five:** Represents happiness.
- **Thumbs Up:** Indicates approval or joy.
- **Fist:** Reflects anger or frustration.
- **Thumbs Down:** Denotes disapproval or dissatisfaction.
- **Pointing Finger:** Expresses confusion or focus.

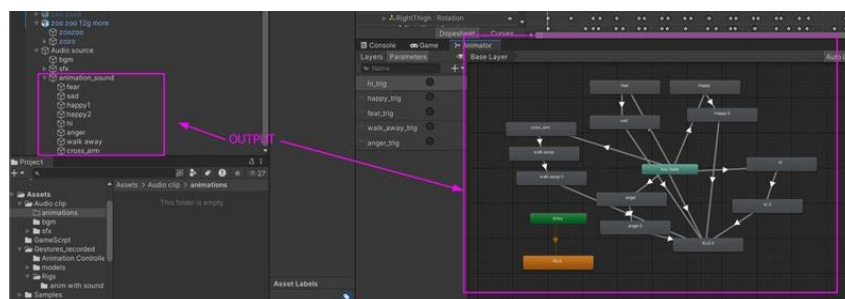


Figure 2: Mapping of gestures with character behavior

4.3 Environment Design

To highlight body language instead of facial expressions, the environment was carefully crafted with low-poly designs and featured a non-human character that lacked any facial features. This intentional choice allowed

researchers to zero in on macro-level body language and gestures without the distractions of facial expressions. Low-poly models were implemented to reduce the graphical processing, to minimize the rendering load on the headset providing a smoother performance.

The study took place in two different settings: a cozy living room and an open park with simple elements, offering diverse contexts for thorough analysis. However, the open-space environment faced performance issues due to its high rendering demands and too many graphical elements, which made it unmanageable within the current system. Consequently, the study shifted to the closed-room VR environment for further development. This smaller space allowed for optimized rendering, cutting down on computational strain while still facilitating meaningful interaction studies.

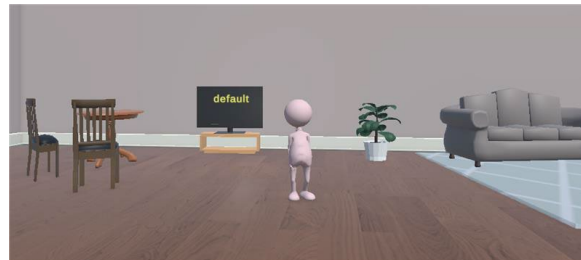


Figure 3: Character places in living room environment and character places in open space

A feedback system was created, using gestures, sounds, and lights to express various moods and emotional states to the player. Bright lights signaled positive responses, creating a cheerful vibe, while shadows represented negative responses, adding a touch of unease. This system was designed to provoke strong emotional reactions and boost player engagement with the character. The virtual reality environment enabled players to view the character and its surroundings from different angles, promoting the players to feel a strong sense of fun, immersion, and emotional connection to the character.

5. Result

The interactive simulation was launched on the Meta Quest 3 VR headset, which participants donned during the testing phase. They were instructed to use specific gestures that had been mapped out beforehand, each intended to provoke responses in the virtual environment. Throughout the sessions, the participants responses and reactions were closely monitored and documented, with a focus on gesture accuracy, caterer interaction, emotional engagement, and behavioral patterns.

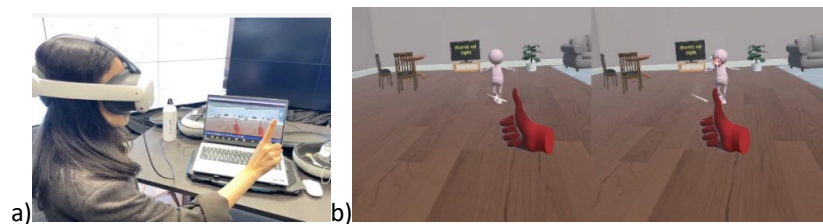


Figure 4: (a) and (b) Gameplay testing with hand gestures

This table shows how certain gestures connect with emotional reactions and user behaviour, providing useful insights for crafting more engaging and meaningful VR experiences.

Table 1: Gestures and Emotional correlation

Gesture	Emotional Response	Player Behaviour	Observations
Fist	Negative emotions, heightened empathy	Players tended to back out of interactions	Elicited strong empathetic responses despite being perceived as hostile gestures.
Thumbs Up	Positive emotions such as happiness and approval	Frequently used by players	This gesture was among the most preferred and encouraged positive interaction.
Wave	Positive and welcoming emotions	Frequently used by players	Triggered friendly interactions and was widely adopted for initial engagement.

Gesture	Emotional Response	Player Behaviour	Observations
Thumbs Down	Negative emotions such as disapproval or frustration	Mixed reactions: some players disengaged	Clearly communicated dissatisfaction or criticism.
Open-Hand Swipe	Neutral or exploratory emotions	Encouraged playful exploration in open spaces	Often associated with testing boundaries or exploring responses.
First (Punch)	Cathartic release of negative emotions, stress relief	Some players expressed satisfaction through repetition	Gestures allow a constructive outlet for stress within the virtual environment.
Point finger	Confused, but neutral	Most of the player were neutral	Generated confusion or a sense of humour with the players

6. Conclusion

This study highlights how using simple, universal gestures in character interactions within virtual reality can really evoke a wide range of emotions from happy, sad, angry and empathy, which can significantly enhance user engagement with the system. The results indicate that participants felt a stronger connection in environments that mimicked enclosed spaces, where interacting with a non-human character through gestures was more responsive and impactful, no spoken dialogue needed. These findings pave the way for exciting applications in nonverbal communication training and emotionally rich interactive storytelling. Looking forward, by improving gesture recognition accuracy and enhancing the emotional feedback system, we can create more intuitive, human-centred virtual reality experiences, especially in areas like education, therapy, and inclusive design. Incorporating universal gestures into different VR settings could truly elevate learning, communication, and immersive storytelling experiences.

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Ethics Declaration: All user testing has been carried out with their clear consent to uphold ethical standards of research.

AI Declaration: No artificial intelligence was used to create the project.

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