ISSN 2579-7298

Comparative Analysis of Usability and Immersivity in Virtual Reality Applications Based Interaction Methods Using Controller and Hand Gesture

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ARTICLE INFO

Article history
Received
Revised
Accepted

Keywords
usability
immersivity
Usability Testing,
Igroup Presence Questionnaire

ABSTRACT

Natural User Interface (NUI) is a latest development in the world of human-computer interaction can applied to immersive digital technology and realized in virtual reality. This virtual reality (VR) is usually accessed using a VR headset, so there are several companies that develop and improve VR headsets to facilitate interaction between humans and computers. One of the VR headsets available for beginners and professionals is the Meta Quest 2 which can be used with two interaction methods, namely, controllers and hand gesture. This study was conducted to compare the usability and immersivity of the two interaction methods on the Meta Quest 2 VR headset. This test was conducted at a Vocational High School in Malang, one of the city in Jawa Timur, in the Visual Communication Design Departement who had never used a VR headset before. There are two methods used, namely, Usability Testing to measure usability and the Igroup Presence Questionnaire (IPQ) method is used to measure immersivity. The applications used in this study are the Waltz of The Wizard Game, The Walking Dead Game: Saints & Sinners and Virtual Reality-Based Applications as Educational Media for Cultural Heritage Buildings in Malang City. The results of the usability and immersiveness tests show that in the Waltz of The Wizard game, it gets a high coefficient value on hand gestures, which is 0.136 and 0.096 on the controller. While in the game The Walking Dead: Saints & Sinners, it gets a high coefficient value on the controller, which is 0.398 and 0.171 on hand gestures. And in the Cultural Heritage Application, it gets a high coefficient value on hand gestures, which is 0.065 and 0.055 on the controller. From the coefficient values, usability and immersivity in the use of controllers are higher in action genre applications, for example the game The Walking Dead: Saints & Sinners. While in hand gestures, usability and immersivity are high when using adventure genre applications, for example the Waltz of The Wizard game and exploration, for example the Cultural Heritage Application game. This means that the interaction method and type of application used determine the level of usability and immersivity

1. Introduction

Natural User Interface (NUI) is a new approach to human-computer interaction, where users interact with systems using natural, everyday behaviors or gestures. NUI aims to provide a more intuitive experience and reduce the barriers between humans and computers (Brandon, 2020). This technology enables innovative forms of interaction through touch, voice, or body movement (Guerino et al., 2020).

One of the main implementations of NUI is immersive digital technology, a technology that combines physical and virtual environments so that users feel as if they are in a real digital world. Virtual Reality (VR) has become the most popular form of immersive technology due to its ability to create interactive three-dimensional environments (Nussipova et al., 2020). Using devices such as VR headsets, users can explore virtual worlds and interact directly through motion sensors, controllers, or hand tracking (Hamad & Jia, 2022).

The development of VR devices, such as the Meta Quest 2, allows for two primary interaction methods: controller-based and hand gesture-based. Controllers offer precise control but require adaptation and learning, while hand gestures provide a more natural experience but are prone to motion recognition errors (Lorenzis et al., 2023). Therefore, it is important to assess the effectiveness of both methods, particularly in terms of usability and immersiveness.

Usability relates to the level of ease and comfort for users in running an application, while immersiveness describes the extent to which users feel present in the virtual environment (Supriyatna, 2019). This study focuses on a comparative analysis of usability and immersiveness between controller-based and hand gesture-based interactions in Meta Quest 2. Testing was conducted at a vocational high school in Malang Regency majoring in Visual Communication Design (DKV), involving students who had never used a VR headset before.

Participants were divided into three groups based on the interaction method used: controller, hand gesture, and a combination of both. They were asked to play three different VR applications—Waltz of the Wizard (adventure), The Walking Dead: Saints & Sinners (action), and Cagar Budaya Kota Malang (exploration)—and then completed a questionnaire to assess their user experience. Usability data was collected using the Usability Testing Method, while immersiveness was measured using the Igroup Presence Questionnaire (IPQ).

This study aims to: (1) compare the level of usability and immersiveness in VR applications with controller and hand gesture interaction methods; and (2) identify the most optimal form of control in supporting user experience on the Meta Quest 2 headset. The results are expected to contribute to the development of more natural interaction designs according to the principles of Natural User Interface (NUI) and improve user experience in Virtual Reality technology.

2. Method

This study uses a comparative quantitative approach that aims to determine the differences in the level of usability and immersiveness in the controller and hand gesture interaction methods using the Meta Quest 2 virtual reality headset. The quantitative approach was chosen because this study focuses on measuring numerical data, statistical analysis, and testing hypotheses objectively and systematically.

The research was conducted in June 2023 at a vocational high school (SMK) in Malang Regency, specifically in the Visual Communication Design (DKV) department. This location was chosen because the students had a relevant background in interactive technology but lacked direct experience using virtual reality devices, allowing for more objective results regarding the user experience.

The population of this study included all Visual Communication Design students who had never used a VR headset before. From this population, 30 students were selected as a sample using purposive sampling based on certain criteria. The sample was then divided into three groups: those using a controller, those using hand gestures, and those using both. This division was intended to facilitate the comparison process between each interaction method in the context of using the MetaQuest 2 virtual reality headset.

The variables examined in this study consist of independent variables and dependent variables. The independent variable is the interaction method used, namely the controller and hand gestures, while the dependent variables are the level of usability and immersiveness. The usability aspect includes five indicators: learnability, efficiency, memorability, error, and satisfaction, while the immersiveness aspect includes four main dimensions: presence, spatial presence, involvement, and experienced realism.

This study used the Meta Quest 2 virtual reality headset and its built-in controller as the primary testing tools. The materials used included three VR-based applications: Waltz of the Wizard, The Walking Dead, and a VR-based educational application themed around cultural heritage buildings in Malang City. These three applications were chosen because they represent a variety of VR usage contexts, ranging from entertainment and simulation to education.

Before the data collection process began, researchers first established the research objectives, prepared the hardware and software to be used, and ensured all components were functioning properly. Afterward, a brief training session was conducted for respondents to introduce them to the headset's use and the interaction methods to be tested. During the implementation phase, participants performed a number of tasks within the application according to the predetermined interaction method groups.

After all testing sessions were completed, respondents were asked to complete a Likert-based questionnaire to assess their experience. Usability was measured using a five-point Likert scale ranging from "strongly disagree" to "strongly agree," while immersiveness was measured using a seven-point scale ranging from "very strongly disagree" to "very strongly agree." The usability questionnaire was adapted from Supriyatna (2019), while the immersiveness questionnaire was adapted from Bayro et al. (2022), which refers to the English version of the Igroup Presence Questionnaire (IPQ).

The data collected from the questionnaires were then analyzed in several stages. First, validity and reliability tests were conducted to ensure the research instrument was suitable for use. Next, classical assumption tests, including normality, multicollinearity, and heteroscedasticity, were conducted as prerequisites for regression analysis. The data were then analyzed using multiple linear regression to determine the effect of interaction methods on usability and immersiveness, and a paired t-test to compare the differences between the controller and hand gesture methods.

In addition to statistical analysis, interpretation was also conducted using Usability Testing methods to assess the quality of the user experience, and the Igroup Presence Questionnaire (IPQ) to measure the level of engagement and realism of the immersive experience. The final results were then categorized based on specific assessment intervals and criteria, which were used to determine the performance of both interaction methods in creating an effective, comfortable, and immersive VR experience for users.

With this systematic research design, it is hoped that the analysis results will provide a comprehensive overview of the effectiveness of controller-based and hand gesture-based interactions in VR technology and serve as a reference for developing more optimal interaction systems in the future.

3. Results and Discussion

3.1 Result

1) Respondent Characteristics

This study involved 30 Visual Communication Design (DKV) students from a vocational high school, divided into three groups. Based on gender, there were 19 male respondents (63%) and 11 female respondents (37%). The number of male respondents was higher because they generally have a higher interest in technology, such as virtual reality applications.

In terms of age, the majority of respondents were 16 years old (67%), while the remainder were 15 years old (33%). The predominance of 16-year-olds indicates that this age group tends to have a strong curiosity and interest in digital technology-based innovations.

2) Research Instrument Testing

The questionnaire in this study served as a data collection tool that must meet validity and reliability requirements to ensure reliable results. Validity testing was conducted to ensure that each

question item accurately measured the intended aspect, both usability and immersiveness. An item is considered valid if the calculated r-value is greater than the calculated r-value (0.05) and the significance value is less than 0.05 (Janna, 2021).

The test results showed that all items in each questionnaire, for both usability and immersiveness, achieved calculated r-values > the calculated r-value and significance values <0.05, thus all items were declared valid.

Table 1. Recapitulation of Questionnaire Validity Test Results

No	Media / Method	Type of Questionnaire	Number of Items	Validity Status
1	*Waltz of The Wizard* (Controller)	Usability	5	Valid
2	*Waltz of The Wizard* (Controller)	Immersiveness	4	Valid
3	*Waltz of The Wizard* (Hand Gesture)	Usability	5	Valid
4	*Waltz of The Wizard* (Hand Gesture)	Immersiveness	4	Valid
5	*The Walking Dead: Saints & Sinners* (Controller)	Usability	5	Valid
6	*The Walking Dead: Saints & Sinners* (Controller)	Immersiveness	4	Valid
7	*The Walking Dead: Saints & Sinners* (Hand Gesture)	Usability	5	Valid
8	*The Walking Dead: Saints & Sinners* (Hand Gesture)	Immersiveness	4	Valid
9	*VR Cultural Heritage Application* (Controller)	Usability	5	Valid
10	*VR Cultural Heritage Application* (Controller)	Immersiveness	4	Valid
11	*VR Cultural Heritage Application* (Hand Gesture)	Usability	5	Valid
12	*VR Cultural Heritage Application* (Hand Gesture)	Immersiveness	4	Valid

Based on Table 4.3, all instruments used in this study were proven valid. This means that each indicator in the questionnaire was able to measure the expected variable construct, both in terms of usability and immersion in virtual reality-based media.

3) Reliability Test

Reliability testing was conducted to measure the internal consistency of the research instrument, namely the extent to which the questionnaire produces stable and reliable results. This test used the Cronbach's Alpha method, where an instrument is considered reliable if the Cronbach's Alpha value is >0.6 (Janna, 2021).

Based on the test results, all questionnaires for the usability and immersiveness variables for the three media tested showed Cronbach's Alpha values above 0.6, thus concluding that all research instruments are reliable. The results indicate that all instruments have good consistency and can be used reliably to measure the level of usability and immersiveness of each virtual reality-based media.

4) Normality Test

A normality test is conducted to determine whether the data used in the study is normally distributed. The test uses the Kolmogorov-Smirnov method, where data is considered normal if the significance value is ≥ 0.05 (Nugraha, 2022).

For example, the results of the normality test for the game Waltz of the Wizard are presented in Table 2 below.

Table 2. Normality Test of the Game *Waltz of The Wizard*

Item	Significance Value	Description
Controller Usability	> 0.05	Normal
Controller Immersiveness	> 0.05	Normal
Hand Gesture Usability	> 0.05	Normal
Hand Gesture Immersiveness	> 0.05	Normal

Similar results were also obtained for the game The Walking Dead: Saints & Sinners and the Malang City Cultural Heritage Virtual Reality Application, where all usability and immersiveness variables had significance values above 0.05. Thus, it can be concluded that the data for all research objects are normally distributed and meet the basic assumptions for further analysis.

5) Multicollinearity Test

A multicollinearity test is conducted to ensure that there is no strong relationship or correlation between the independent variables in the regression model. The test is conducted by examining the Tolerance and Variance Inflation Factor (VIF) values. Data are considered free from multicollinearity if the Tolerance value is >0.1 and the VIF is <10 (Nugraha, 2022).

Based on the test results, all independent variables in the three research objects (Waltz of the Wizard, The Walking Dead: Saints & Sinners, and the Malang City Cultural Heritage Application) demonstrated Tolerance and VIF values that met these criteria. Therefore, it can be concluded that the regression model used is free from multicollinearity.

3.2 Usability Analysis Using Usability Testing Methods

The results of the usability questionnaire were obtained from 30 respondents divided into three groups of 10 people each. Each group tested three virtual reality applications using different interaction methods. This section discusses the results of testing using the controller interaction method.

1. Using the Controller Interaction Method

a. Waltz of the Wizard Game

Based on the questionnaire results shown in Table 4.22, the average scores for each usability aspect were learnability (4.45), efficiency (4.20), memorability (4.35), error (4.15), and satisfaction (3.85). Overall, these results indicate that Waltz of the Wizard Game has excellent levels of learnability and memorability, although user satisfaction is still considered good but not dominant.

Table 3. Evaluation Criteria Results for the Game *Waltz of The Wizard* – Controller Usability

No	Variable	Mean	Criteria
1	Learnability	4.45	Very Good
2	Efficiency	4.20	Good
3	Memorability	4.35	Very Good
4	Error	4.15	Good
5	Satisfaction	3.85	Good

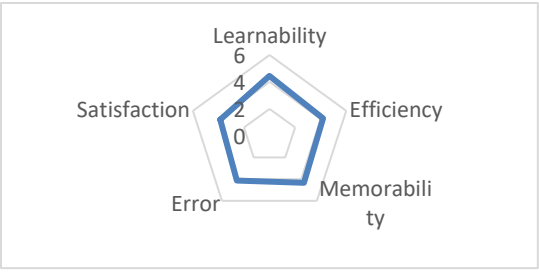

Fig. 1. Usability Mapping Graph for Waltz of the Wizard Using a Controller

b. The Walking Dead: Saints & Sinners Game

The usability assessment results for this game showed consistently high average scores across all aspects, with the highest scores in the learnability (4.45) and satisfaction (4.25) variables. This

indicates that users found it easy to learn the game controls and experienced high levels of satisfaction while playing.

c. Virtual Reality-Based Cultural Heritage Application

For this educational application, the average score was in the good range, with the highest score in the satisfaction aspect (4.23). This finding indicates that despite the relatively high interaction complexity, users were still satisfied with the experience.

Overall, the usability test results using the controller interaction method showed that:

- The Walking Dead: Saints & Sinners game had the highest usability score among the three applications.
- Waltz of the Wizard game demonstrated strong performance in the learnability and memorability aspects.
- The Cultural Heritage application excelled in satisfaction, although its error and efficiency aspects were slightly lower.

All three apps were rated equally good to excellent, demonstrating that VR controller-based controls are capable of providing an intuitive and engaging experience for users.

2. Using the Hand Gesture Interaction Method

a. Waltz of the Wizard Game

Table 4. Evaluation Criteria Results for the Game *Waltz of The Wizard* – Hand Gesture Usability

No	Variable	Mean	Criteria
1	Learnability	4.45	Very Good
2	Efficiency	4.05	Good
3	Memorability	4.15	Good
4	Error	4.40	Very Good
5	Satisfaction	4.10	Good

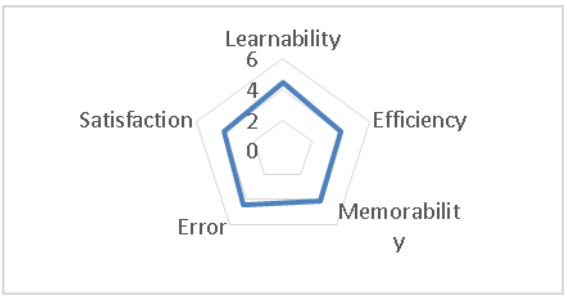

Fig. 2. Usability Mapping Graph for Waltz of the Wizard Using Hand Gestures

Figure 4.4 shows that learnability and error are the highest-scoring variables, with a very good rating. This indicates that users easily adapt to hand gestures and rarely make errors during interactions.

b. Game The Walking Dead: Saints & Sinners

Table 5. Evaluation Criteria Results for the Game *The Walking Dead: Saints & Sinners* – Hand Gesture Usability

No	Variable	Mean	Criteria
1	Learnability	3.95	Good
2	Efficiency	4.10	Good
3	Memorability	4.05	Good
4	Error	3.95	Good
5	Satisfaction	3.88	Good

Based on the average scores in Table 4.32, all aspects are in the good category. However, efficiency was the highest, indicating that hand gestures are still effective even though the game requires quick responses. Some respondents stated that interaction is more comfortable with a controller, as the game genre demands precise movements.

c. Virtual Reality-Based Cultural Heritage Application

Table 6. Evaluation Criteria Results for the *Virtual Reality Cultural Heritage Application* – Hand Gesture Usability

No	Variable	Mean	Criteria
1	Learnability	4.10	Good
2	Efficiency	4.05	Good
3	Memorability	4.50	Very Good
4	Error	4.25	Very Good
5	Satisfaction	4.15	Good

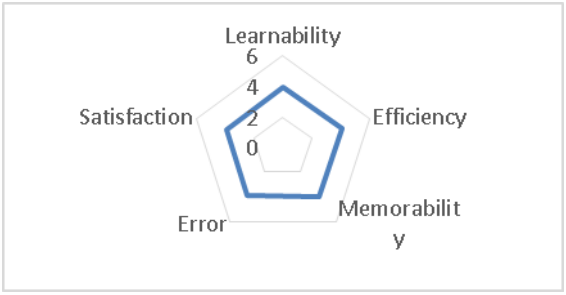

Fig. 3. Usability Mapping Graph on Cultural Heritage Applications Using Hand Gestures

It appears that memorability and accuracy (memorability and error) are the highest. Users easily remember gestures and can interact without significant errors. This score supports the app's educational function, as natural hand movements make it easier for users to explore cultural objects.

d. Comparative Analysis of Hand Gesture Usability

Based on the three tests, it can be concluded that the hand gesture interaction method has a good level of usability overall. The highest average scores were found in the Waltz of the Wizard game (4.23) and the Cultural Heritage application (4.21). Both utilize natural movements, supporting immersion and user comfort. Meanwhile, The Walking Dead: Saints & Sinners performed well but not as optimally as the other two applications because the shooting interaction is more appropriate when using a controller.

e. Respondents' Experiences Using the Hand Gesture Method

Respondents provided a variety of responses, indicating preferences for game context and movement type. In general:

- In Waltz of the Wizard, 90% of respondents stated that the hand gesture method was most suitable because the movements were natural and enjoyable.
- In The Walking Dead: Saints & Sinners, 80% of respondents considered the interaction less effective without a controller.
- In the Cultural Heritage Application, most respondents considered hand gestures to facilitate navigation and provide a realistic sense of interactivity.

Thus, the use of hand gestures is most effective in applications with exploratory interactions and object recognition, while for action games based on quick reactions, controllers are superior.

Immersiveness Analysis Using the Igroup Presence Questionnaire Method

1. Using the Controller Interaction Method

a. Game Waltz of The Wizard

Table 7. Evaluation Criteria Results for the Game *Waltz of The Wizard* (Controller Immersiveness)

Variable	Mean	Criteria	Description
Presence	4.35	B	Very Good
Spatial Presence	4.80	B	Very Good
Involvement	4.65	B	Very Good
Experienced Realism	4.60	A	Excellent

The results showed the highest scores in the Spatial Presence (4.80) and Experienced Realism (4.60) aspects. This means that using the controller can provide a high sense of presence and realism for users because the grip-based interaction feels natural.

b. Game The Walking Dead: Saints & Sinners

Table 8. Evaluation Criteria Results for the Game *The Walking Dead: Saints & Sinners* (Controller Immersiveness)

Variable	Mean	Criteria	Description
Presence	4.25	B	Very Good
Spatial Presence	5.40	A	Excellent
Involvement	4.70	B	Very Good
Experienced Realism	4.55	A	Excellent

The Spatial Presence score reached the highest 5.40 across all tests because the controller allows users to feel truly immersed in the action environment. Respondents stated that the shooting and combat experience felt very realistic.

c. Malang City Cultural Heritage Application

Table 9. Evaluation Criteria Results for the *Cultural Heritage Application* (Controller Immersiveness)

Variable	Mean	Criteria	Description
Presence	4.05	C	Good
Spatial Presence	4.82	B	Very Good
Involvement	4.49	C	Good
Experienced Realism	4.35	B	Very Good

The Spatial Presence aspect is the strongest (4.82) because the controller makes it easier to navigate between 3D objects. However, the levels of Presence and Involvement are lower than in games, because the user's focus is not on action but on exploration.

2. Using the Hand Gesture Interaction Method

The results of the Igroup Presence Questionnaire (IPQ) analysis show that both the controller and hand gesture methods provide a high level of immersion across all four variables: presence, spatial presence, involvement, and experienced realism.

In general, the hand gesture method tends to provide a more natural and interactive experience, especially in terms of spatial presence and involvement, because users can interact directly without additional tools. However, in applications with complex gameplay like The Walking Dead: Saints & Sinners, the controller method performed better in terms of control and interaction precision.

Meanwhile, in the educational application "Cultural Heritage of Malang City," both methods showed nearly equal results, with a slight advantage in spatial presence for hand gestures. This suggests that the application context significantly influences the effectiveness of the interaction method used.

Overall, the controller method is more suitable for activities that require high precision, while hand gestures excel at creating exploratory and realistic experiences in virtual environments.

Multiple Linear Regression Analysis

Multiple linear regression analysis was used to determine the effect of controller interaction methods and hand gestures on usability and immersiveness variables. The regression equation model used is:

$$Y = a + b_1X_1 + b_2X_2 + e$$

where YYY represents usability or immersiveness, X1X_1X1 the controller, and X2X_2X2 the hand gesture.

The analysis results show that in Waltz of the Wizard, the regression constants are 3.434 for usability and 2.794 for immersiveness. Meanwhile, in The Walking Dead: Saints & Sinners, the constants are 6.086 (usability) and 6.109 (immersiveness), and in the Cultural Heritage Application, they are 1.677 (usability) and 1.403 (immersiveness). These constant values indicate the baseline level of usability and immersiveness when the independent variables are held constant.

The regression coefficients for the controller and hand gesture variables also showed a positive relationship across all objects. This means that increased use of these two interaction methods is directly proportional to improvements in usability and immersiveness. While the magnitude of the effect varied between applications, a consistent positive relationship pattern was found across all three.

Paired T-Test Analysis

A paired t-test was conducted to determine significant differences between two interaction methods, namely controller and hand gesture, on usability and immersiveness variables. The test was conducted at a significance level of 0.05. A significance value <0.05 indicates a significant difference between the two methods.

The test results showed that in Waltz of the Wizard, The Walking Dead: Saints & Sinners, and the Cultural Heritage application, there were significant differences between the two interaction methods. This indicates that the interaction methods have different impacts on the user experience.

Visualizations of the test results are shown in Figures 4.7 and 4.9, each depicting the t-test results for each application. Overall, the hand gesture method tended to provide a higher level of immersiveness, while the controller excelled in aspects of stability and interaction control.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Mean_Controller - IMean_Controller	2,55000	2,50210	,55949	1,37898	3,72102	4,558	19	,000
Pair 2	Mean_HandGesture - IMean_HG	2,95000	1,66938	,37329	2,16870	3,73130	7,903	19	,000

Fig. 4.T-Test Results on the Waltz of the Wizard Game

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Mean_C - IMean_C	2,60000	1,56945	,35094	1,86548	3,33452	7,409	19	,000
Pair 2	Mean_HG - IMean_HG	2,70000	1,94936	,43589	1,78767	3,61233	6,194	19	,000

Fig. 5.T-Test Results on The Walking Dead: Saints & Sinners Game

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Mean_C - IMean_C	3,40000	1,66702	,37276	2,61981	4,18019	9,121	19	,000
Pair 2	Mean_HG - IMean_HG	3,05000	1,60509	,35891	2,29879	3,80121	8,498	19	,000

Fig. 6.T-Test Results on Cultural Heritage Application

Discussion

The results of the data analysis provide an in-depth overview of the influence of controller interaction methods and hand gestures on usability and immersiveness in the user experience of virtual reality-based applications. This discussion outlines the results of instrument testing and the classical assumption analysis that underpins the validity of the research data.

1. Research Instrument Testing

Instrument testing was conducted to ensure that the data collection tool had adequate validity and reliability. Based on the results of the validity test using SPSS v25, the calculated r-value was greater than the table r-value (0.4438), and the significance value was <0.05, indicating that all instrument items were valid.

Furthermore, the reliability test results showed a Cronbach's Alpha value >0.6, demonstrating that the research instrument was reliable and consistent in measuring the variables studied. Therefore, the questionnaire used in this study met the validity and reliability criteria for use in the next stage of analysis.

2. Classical Assumption Analysis Test

The classical assumption test was conducted to ensure that the regression model met statistical requirements and produced accurate estimates. Three types of tests were performed:

a. Normality Test
   The Kolmogorov–Smirnov test results showed that all data had a significance value above 0.05, for both the usability and immersiveness variables. Therefore, the data were normally distributed and suitable for use in regression analysis.
b. Multicollinearity Test
   Based on the test results, the tolerance value was 1.00 and the VIF was 1.00, meaning the tolerance was > 0.1 and the VIF was < 10. These results indicate that there is no correlation between the independent variables, thus the model is free from multicollinearity.
c. Heteroscedasticity Test
   The Glejser test showed a significance value greater than 0.05, indicating that the data are free from heteroscedasticity or non-constant residual variance.

3. Comparative Analysis of Usability and Immersiveness between Controller and Hand Gesture

Based on the analysis, we obtained a comprehensive overview of the differences in usability and immersiveness between controller and hand gesture interaction methods in three applications: Waltz of the Wizard, The Walking Dead: Saints & Sinners, and the Malang City Cultural Heritage application.

Overall, the analysis showed that in The Walking Dead: Saints & Sinners, using a controller resulted in the highest usability score, with a total score of over 21 (very good), particularly in the learnability, efficiency, and satisfaction categories. This indicates that controllers are optimal for action-based applications because they provide precise control and fast response. Meanwhile, in Waltz of the Wizard and the Malang City Cultural Heritage application, the hand gesture method scored higher, particularly in the memorability and error dimensions, indicating ease of recall and low error rates during interaction.

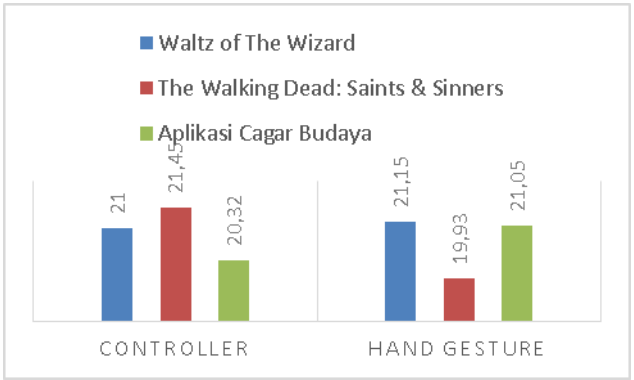

Fig. 7. Comparison Graph of Usability Assessment Criteria Results for Controller and Hand Gesture Interaction Methods

The comparison of the average usability scores between the two methods is visualized in Figure 5.1, which shows that the controller is superior in action applications, while hand gestures are superior in adventure and exploration applications. Thus, user preference for interaction methods is influenced by the characteristics of the activity within the virtual environment.

A similar pattern was also found in the immersive aspect. Controller use in The Walking Dead: Saints & Sinners scored highest, particularly on the dimensions of spatial presence and experienced realism, indicating that users felt more engaged and engaged in the fast-paced action simulation. Conversely, in Waltz of the Wizard and the Cultural Heritage application, the hand gesture method demonstrated a higher total immersiveness score, primarily due to the more natural interaction and freedom of movement users experienced in the virtual environment. These results are illustrated in Figure 5.2, which compares the levels of immersiveness between the two interaction methods.

The resulting regression coefficient values also support these findings. In The Walking Dead: Saints & Sinners, the controller had a usability coefficient of 0.398 and an immersiveness of 0.177, higher than hand gestures. Conversely, in Waltz of the Wizard and the Cultural Heritage Application, hand gestures demonstrated higher usability and immersiveness coefficients than the controller. A comparison graph of these coefficient values can be seen in Figure 5.3 for usability and Figure 5.4 for immersiveness.

These results indicate that the controller provides the best experience for action genre applications, while hand gestures are more appropriate for adventure and exploration genres. Documentation of respondents' activities using controller-based interaction methods is shown in Figure 5.5, while a screenshot of The Walking Dead: Saints & Sinners can be seen in Figure 5.6.

Based on observations during testing, respondents felt that the controller was faster and more accurate in translating motion input and more familiar because it resembled a conventional gaming device. These factors contribute to user comfort in action-based games.

In contrast, documentation of the use of hand gesture-based interaction methods is shown in Figure 5.7, with examples of implementation in the game Waltz of the Wizard (Figure 5.8) and the Malang City Cultural Heritage Application (Figure 5.9). In this context, hand gestures are considered to provide a more natural experience because users can interact directly without additional devices and have the freedom of movement to mimic real-life activities.

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4. Conclusion

Based on the research conducted, it can be concluded that the interaction methods on the Meta Quest 2 headset, whether using a controller or hand gestures, significantly impact the level of usability and immersiveness when users interact with virtual reality applications. The results show that using a controller results in a higher level of usability and immersiveness in action genre applications, such as The Walking Dead: Saints & Sinners. This is because the controller is able to respond quickly to user input and feels more familiar in use.

In contrast, hand gesture-based interaction methods demonstrated superiority in adventure and exploration genre applications, such as Waltz of the Wizard and Cultural Heritage Applications. The use of hand gestures allows users to interact more naturally and freely, thus creating a stronger sense of involvement and immersion in the virtual environment. Thus, it can be concluded that the effectiveness of interaction methods on virtual reality devices is highly dependent on the type or genre of application used, where controllers are more suitable for applications with a high level of action, while hand gestures are more optimal for applications that emphasize exploration and natural interactive experiences.

Furthermore, the optimal form of control when using hand gestures in Meta Quest 2 is also highly determined by the context in which the application is used. In adventure and exploration applications, natural hand gestures such as waving, pointing, or grasping are the most effective forms of interaction because they are easy to understand without requiring special instructions. However, in action genre applications, hand gestures are less optimal because they require a higher level of accuracy and speed in detecting and translating complex movements. Therefore, the implementation of a Natural User Interface (NUI) realized through hand gestures needs to be adapted to the characteristics and needs of each type of application to provide a maximum user experience.

Acknowledgment

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g.” Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

Declarations

Author contribution. The contribution or credit of the author must be stated in this section.
Funding statement. The unding agency should be written in full, followed by the grant number in square brackets and year.
Conflict of interest. The authors declare no conflict of interest.
Additional information. No additional information is available for this paper.

Data and Software Availability Statements

Data and Software availability statements provide a statement about where data and software supporting the results reported in a published article can be found, including hyperlinks to publicly archived datasets and software analyzed and generated during the study/experiments.

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