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Comparison Analysis of Usability Using Controllers and Hand Tracking in Virtual Reality Gamelan (Saron) Based On User Experience

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Abstract: Gamelan is one of the traditional musical instruments in Indonesia. Gamelan is also one of the cultures that must be preserved. To preserve gamelan, one way is by combining gamelan with technology that is currently developing. The technology that is currently trending is virtual reality. Virtual reality is often used for games in three-dimensional form. Gamelan can be something interesting in VR. In VR interactions, there are two interactions that are often used, namely controllers and hand tracking. Hand gestures are usually tracked using the built-in camera of the VR. Hand tracking can be used in VR applications to control the virtual object just like a controllers. This study aims to compare the use of controllers and hand tracking that involve interactions, namely collision, pressing, grabbing, and release. Thirty two Atma Jaya Yogyakarta University students who had tried virtual reality and played gamelan or had seen gamelan performances explore the differences between VR hand tracking and VR controllers in VR gamelan saron. SUS (System Usability Scale) and USEQ (Use Questionnaire) were used to measure user usability and satisfaction. The result of the SUS score showed that users were more interested in using controllers than hand tracking. But the USEQ results showed that there were no difference in usefulness, ease of use, and satisfication. Based on the results of the interaction, using controllers looked more comfortable, but using hand tracking, playing gamelan looked more realistic.

Keywords: virtual reality • controllers • hand tracking • usability • VR interaction

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1. Introduction

Traditional music is regional music that is sustainable and passed on to the community from generation to generation. Gamelan is a well-known example of traditional music [1]. Gamelan is one of the various kinds of Indonesian cultural wealth [2]. The value of knowledge about Indonesian culture is reflected in the gamelan, which is Indonesia's cultural heritage. Gamelan music can be known as karawitan, which is an expression of traditional music from Java, Indonesia [3]. One way of preserving gamelan so that the current generation is interested is by making a game-based gamelan technology [4].

In recent decades, information systems and communication technologies have played an important role in the digital world. Rapid technological change is one of the reasons for achieving competitive advantage [5]. One technology that is currently trending is Virtual Reality [1]. "Virtual Reality" is a simulation generated from a three-dimensional environment where users will interact in a way that looks real. The current standard virtual reality system uses a head-mounted VR headset (HMD) [6].

A Head-mounted Display (HMD) is a device that is worn on the head as part of a helmet with a built-in lens and screen [7]. Users can interact with objects in the virtual world and can see their surroundings in a 360-degree angle using HMDs [7–9]. The HMD makes the virtual world visible to the user with the help of wide viewing angles, tracking of hand and head movements, and objects [7]. HMDs can reflect high realism and sketches of the real world [9, 10].

A good design of the VR simulation can provide a different perspective for the user. For example, people who are shorter and taller experience different experiences in the real world. In VR, the user can interact with the virtual world to simulate different scenarios. VR surrounds the user as if they are moving and seeing in a different reality than the real thing and provides optimal auditory and visual stimulation. VR also provides an opportunity to learn to interact with the lesson directly [11].

The point of user realization in a virtual environment is the extent to which users feel the experience of being in a virtual world. An important factor in immersing virtual reality also lies in the accurate and timely representation of the user's hand in the virtual environment. If the user can see the virtual hand and its movement relative to the object, it is likely that the user can feel that the user can do something using his hand in the virtual world [12]. Over time, user knowledge retention will improve [13].

The continuous improvement and development of virtual reality devices has been demonstrated in new applications and the latest head-mounted display features. Technological advances accompanied by the interaction of ideas in the virtual world allow users to interact realistically with the virtual environment. The goal is to bring users into the virtual world with the same interactions as in the real world. One idea that can be researched is to use hand tracking to replace the controllers as an interaction tool in the virtual world [14].

At the end of 2019, Oculus released hand tracking for their VR Quest headset [15]. Hand tracking is a new technology in VR to detect the user's hand movement and position using the internal camera on the VR headset. VR applications can use hand tracking to manipulate objects and control touch by detecting the hand and detecting the user's hand as if the user were using a controllers [16, 17]. Users can use Oculus Quest to make it easy for users to access and use VR at home [15]. With no additional purchases, VR headsets currently offer a controllers as an essential accessory [16].

The way hand tracking works is by using the inside-out camera on the VR headset [14, 15, 18]. The headset detects the position, finger configuration, and orientation of the user's hand. Once detected, the computer vision algorithm will track the orientation and movement of the user's hand. The hand tracking system detects hand movement as a controller where the user can press a button using the applicable hand. Usually, the user can be tracked from any angle and position around the headset [14]. With hand tracking, the user's hand must be seen by the tracking camera on the Oculus while doing something [15].

Although virtual reality is just gaining momentum and achieving commercial success, hand tracking is not a new concept [19]. Modern hand tracking in virtual reality relies on the inside-out camera sensor on the HMD [15, 19]. In the future, inside-out hand tracking will be popular due to its ease of use and lack of accessories [14, 20]. However, hand tracking using inside-out technology may not provide accurate real-time hand detection [14]. Using controllers and hand tracking has several characteristics that must be considered for interactions in VR from an accuracy perspective to provide accurate control results. VR simulation must ensure a good user experience and quality [14, 21]. The difference in interaction between controllers and hand tracking can be compared using the Mann-Whitney test [16, 22, 23].

In 1947, Mann and Whitney proposed a method based on the comparison of each observation in the first sample with other samples. The Mann-Whitney test is a test used to determine the comparison of the differences between two independent groups. The Mann-Whitney test compares the similarity of the distribution of dependent variables for two groups of the same population. The test rating of all dependent values, i.e., the lowest score gets a score of one, then uses the number of ratings for each group in the calculation of the statistical test [22, 23].

The subjective usability response of the application can be measured using a standard questionnaire designed using a likert scale. The SUS offers a comprehensive, global perspective on subjective evaluations of usability. The way to use SUS is write 10 predetermined questions of SUS with 1-5 likert scale [24]. For usefulness, ease of use, and satisfication can be assesed using USEQ [25].

Hand tracking using inside-out technology may not yet provide accurate real-time hand detection. Further studies are needed to put this technology into practice based on its effectiveness. This study focuses on VR applications for game because it focuses on realistic results. The direct interaction between the application and the user is related to the choice of its control scheme. It is interesting to analyze the effect of using controllers and hand tracking on the usability of VR applications [14]. This study aims to determine the differences in the use of controllers and hand tracking when applied to VR applications.

1.1. Interaction Design and Implementation

This experiment was designed by developing a VR application that places users in a VR environment to compare interactions between hand tracking and controllers. The case study in this research is the Virtual Reality Gamelan saron Participants in this study were students at Atma Jaya University Yogyakarta who had tried virtual reality and played gamelan or had seen gamelan performances to ensure that the results were based on the real world.

In the tested VR applications, there are four main interactions: collision, pressing, grabbing, and release as shown in Figure 1. Collision is used to inspect the contact between the object and the virtual hand on each snapshot. Some objects have geometric motions and can match collisions with virtual hands. Pressing is used for hitting, touching, pressing, etc. Object Grabbing is used to pick up an object where the object will move according to the virtual hand. In the interaction between the object and the user, the user is made aware of the animation displayed on the object. Release is used to release an object that has already been retrieved and waits for a new command from the user. The workflow of the VR Gamelan saron game are shown in the Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7. The differences interaction between VR controllers and VR hand tracking are shown in Table 1.

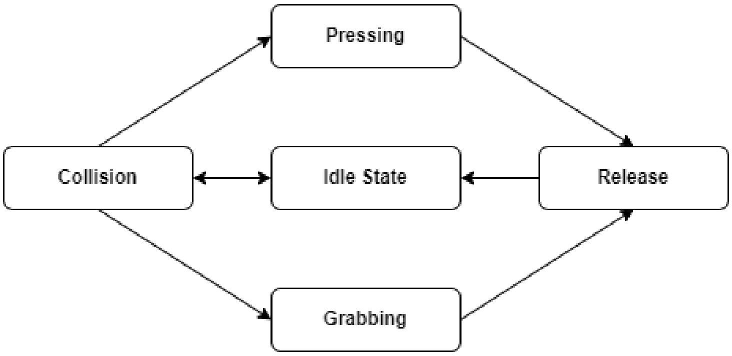
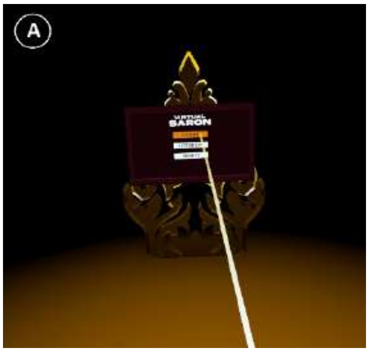
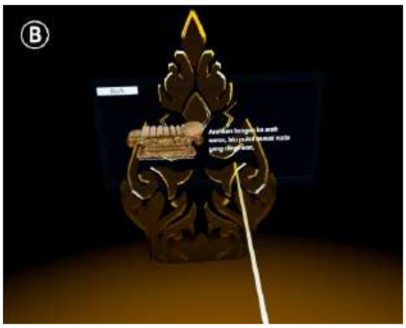


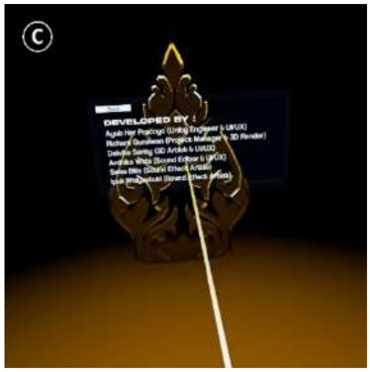
Figure 1: Workflow of the VR gamelan saron's interaction state



(a) Main menu scene VR Gamelan saron



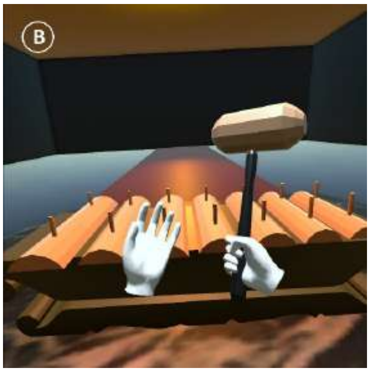
(b) Tutorial for Gamelan Saron in tutorial scene



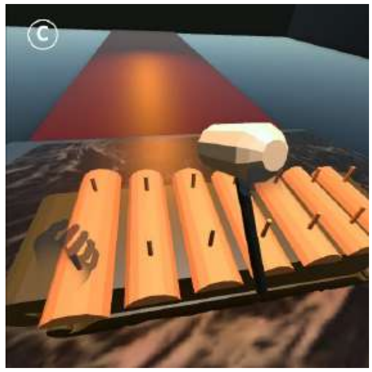
(c) Developer name in about scene

Figure 2: The workflow of the VR Gamelan Saron game

(a) Front view of Gamelan Saron's stage



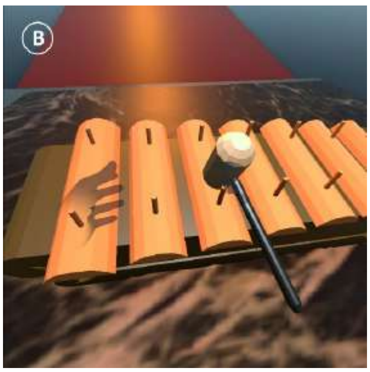
(b) After walking from the front of the stage, grabbing Gamelan Saron's bet with controllers



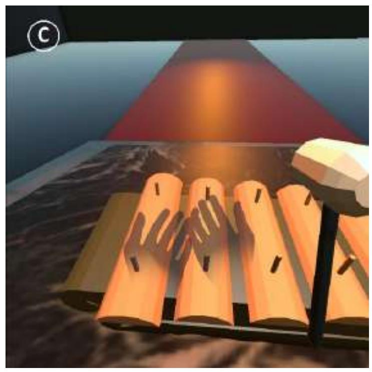
(c) Grabbing gamelan's bet with hand tracking

Figure 3: The workflow of the VR Gamelan Saron game

(a) After grabbing the gamelan, hitting gamelan Saron with Controllers



(b) Grabbing gamelan Saron's bet with hand tracking



(c) Release gamelan's bet with hand tracking

Figure 4: The workflow of the VR Gamelan Saron game

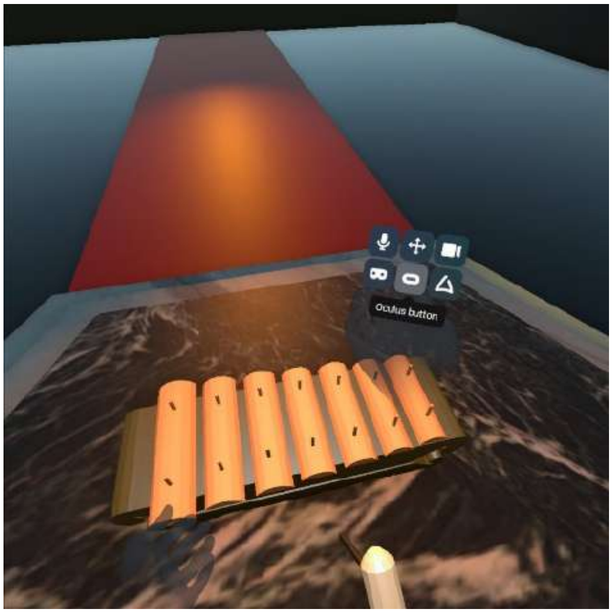


Figure 5: Pressing the occulus button to quit the game with hand tracking

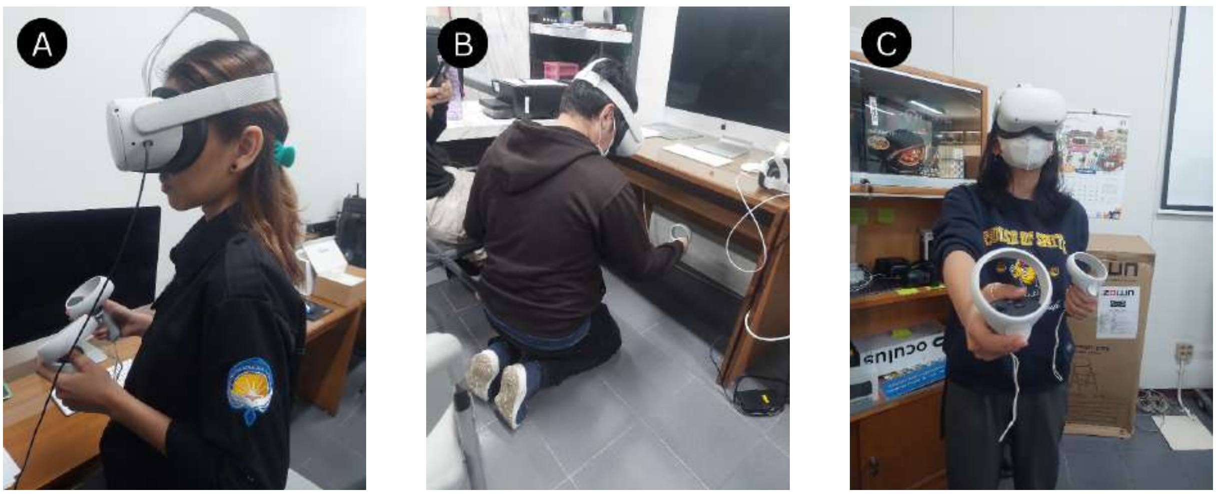


Figure 6: VR gamelan Saron experiment: (A), (B), and (C) VR controllers group

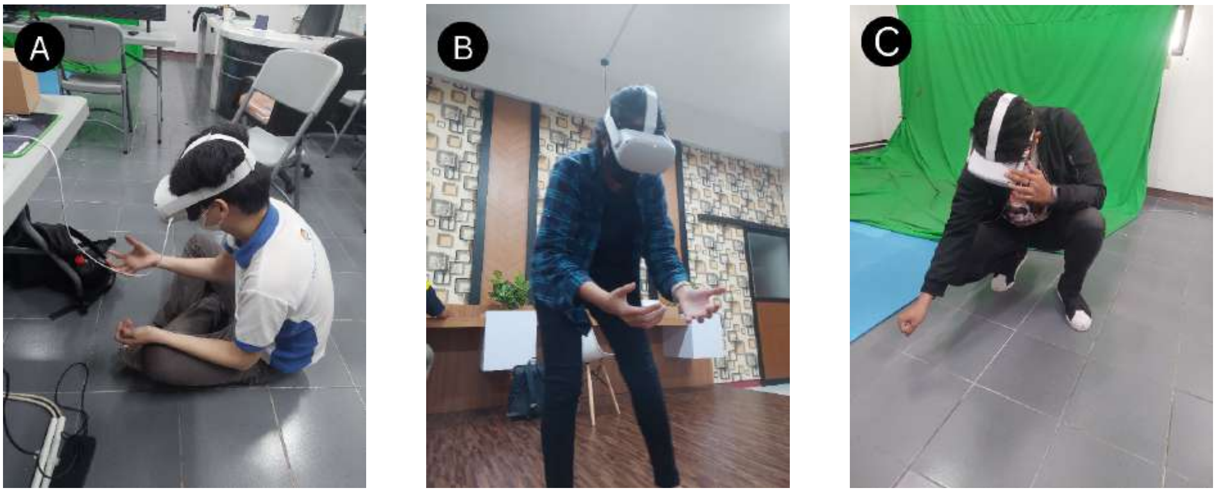


Figure 7: VR gamelan Saron experiment: (A), (B), and (C) VR hand tracking group

Table 1: Differences interaction between hand tracking and controllers

Interactions	Hand Tracking	Controllers
Collision	Virtual hand collision	Virtual hand collision
Pressing	Pressing with hand gesture recognition on VR hand tracking and hold on	Press the PrimaryIndexTrigger button on Controllers
Grabbing	Grabbing with hand gesture recognition on VR hand tracking and hold on	Press and hold on the PrimaryHandTrigger button on Controllers.
Release	Release with hand gesture recognition on VR hand tracking	Release the button after Pressing or Grabbing

For this study, a VR headset with controllers and hand-tracking technology is necessary. The Oculus Quest, which has Touch controllers and Hand-Tracking functionality, supports both technologies, making it a suitable tool for the experiment. As a result, the Oculus Quest with Touch controllers served as the foundation for the interaction technique's design. The buttons on a controller can be used to send commands while implementing interaction design. For pressing and grabbing, respectively, our VR application for virtual reality gamelan Saron used the buttons PrimaryHandTrigger and PrimaryIndexTrigger (as depicted in Figure8). Instead of controllers, the user sees virtual hands that interact with the scene by detecting collisions with specific objects.

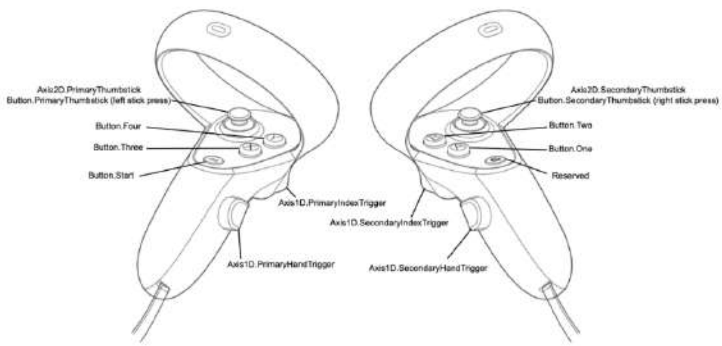


Figure 8: Unity's Oculus Touch Controllers mapping. (source: developer.oculus.com)

2. Methods

This research topic served as the basis for the experiment, which was designed to compare the usability of two interactions used to build a VR application. Thirty two students at Atma Jaya Yogyakarta University (undergraduate) who had tried VR and played gamelan or watched gamelan performances voluntarily took part in our experiment. Thirty two students from Atma Jaya Yogyakarta University were divided into two groups, VR controllers and VR hand tracking, and they each took part in various interactions. In all tasks, the techniques were the identical, but depending on the group.

The VR hand-tracking group made use of hand motions and the VR controllers group interacted using a controllers. The USE Questionnaire (USEQ) with 5-point likert-scale questionnaires and System Usability Scale (SUS) was used to evaluate usability and satisfaction [24]. VR applications' usability was evaluated using the SUS. Usefulness, ease of use, and satisfaction were assessed using the USEQ [25].

All participants were given a brief introduction to the fundamental commands for the VR program prior to training. The VR hand tracking group has learned how to use hand motions for interactions, while the VR controllers group learned how to use controllers. All participants in both groups were welcome to try the VR Gamelan Saron for three minutes at the beginning of the experiment. Then, each participant was asked to try the VR Gamelan Saron application to evaluate interactions according to a predetermined group. The hand tracking group. The hand tracking group used hand gestures and the controllers group used controllers to interact. After using the app, all participants were asked to evaluate the application by answering the SUS and USEQ questionnaires.

Finally, interviews were conducted with several student representatives from the hand tracking group and the controllers group. Each student representative took 5 minutes to be interviewed. The questions for interviews were about emotional, instrumental, and motivating experience. There were also questions about the opinions and feelings of the participants, as well as suggestions for the development of VR Gamelan Saron. In addition to the questionnaires, interviews with participants provided further developmental information and explored the factors that influence usability and satisfaction with VR.

3. Results

Table 2 shows the results of the normality test performed on the SUS scores for both groups in relation to the normal distribution. The differences is SUS scores were analyzed using an independent t-test as a stastical model. However, the USEQ score of usefulness, ease of use, and satisfaction are non-parametric distributions. Therefore, each USEQ score between the VR controllers group and VR hand-tracking group was analyzed using the Mann-Whitney U test.

3.1. SUS Score

The SUS score for VR controllers was 74.53, while the score for VR hand tracking was 64.38. As a result, the VR controllers was nearly satisfactory, while VR hand tracking was deficient. Table 3 shows that the SUS score for both interaction were significantly different because 0.044 < 0.05.

Table 2: Normality test of SUS scores and USEQ scores of each criterion (* normal distribution $\rho > 0.05$).

	Group	**Group**	**Mean**	**SD**	**Statistic**	ρ-Value
SUS (100)	SUS scores	Controllers	74.53	14.95	0.951	0.498*
		Hand Tracking	12.23	64.38	0.975	0.912*
USEQ (5)	Usefulness	Controllers	4.62	0.46	0.773	0.001
		Hand Tracking	4.07	0.83	0.888	0.052*
	Ease of use	Controllers	4.62	0.51	0.734	0.000
		Hand Tracking	4.20	0.74	0.893	0.063*
	Satisfication	Controllers	4.08	0.45	0.933	0.247*
		Hand Tracking	3.62	0.84	0.947	0.450*

Table 3: Results of the independent sample t-test for SUS scores.

Group	**Mean**	**SD**	**SE**	**t**	ρ**-Value**
Controllers	74.5313	14,95044	3,73761	2.103	0.044
Hand Tracking	64.3750	12,23043	3,05761		

3.2. USEQ Scores

As shown in Table 4, the usefulness, ease of use, and satisfaction were not different between the two interaction. The result suggested that there was no difference in usability and satisfication for the VR Gamelan Saron while using controllers or hand tracking.

Table 4: Mann-Whitney U test results for VR Gamelan Saron's usefulness, ease of use, and satisfication.

Usability Scale	Group	Mean Ranks	Sum Ranks	U	ρ-Value
Usefulness	Controllers	19.56	313	79	0.055
	Hand Tracking	13.44	215		
Ease of use	Controllers	19.38	310	82	0.071
	Hand Tracking	13.63	218		
Satisfication	Controllers	19.47	311.5	80.5	0.072
	Hand Tracking	13.53	216.5		

3.3. Interview Results

The majority of participants recommended others use VR gamelan Saron application, because it was simple to comprehend, something different to try, and good experience using VR gamelan Saron. From the results of interview, there were differences in terms of stability of VR gamelan Saron application between the used of hand tracking and controllers: The hand tracking group informed that sometimes repeated interactions due to missing tracking and a little bit lag. All participants also liked the 3D models (stage, gamelan, stage lighting, and gamelan beaters) that felt like a real stage performance.

Emotional experience, positive comments from the participants were "It was like playing regular gamelan in a real situation, but it felt more exciting, because playing gamelan in virtual reality", "Trying vr gamelan Saron game was fun because it was the first time playing gamelan in virtual", "Very happy to tried vr gamelan Saron game", "New experience to tried gamelan in virtual reality", "The atmosphere of play felt calm", "It was fun because we can see our own hand movements in virtual reality hand tracking". Some of the participants gave feedback to improve VR gamelan Saron application: "Can't feel to played on its features because of a little bit lag in hand tracking, maybe the lag can be removed" and "The viewing angle was too low, maybe the point of view can be raised a little bit".

Instumental experience, positive comments from participants were "The lightning from the side of the stage created an atmosphere that gave a warmer impression", "In terms of objectivity of musical instruments, beaters, stage, etc., was good", "The beaters, gamelan, stage, and lightning were appropriate and good", "felt like being in a gamelan show", "Already similar to the original form of gamelan Saron", "Instruments such as bat, gamelan, lightning, and the stage were good and interesting, so we were interested in playing". Some feedback for improvement from the participant: "There was still empty space to fill with other gamelan tools so that we could play multiplayer", "Had to pick up the gamelan bat according to the grab point in hand tracking, maybe the grab point can be lowered a little so it was easy to pick them up", "The gamelan was a little bit big to reach from left to right, so the size must be reduced a little", "The gamelan game could have the feature of holding "pathet" the tone of the gamelan that called "bilah", so it can be more realistic to play", and "The sustain of the gamelan should be reduced a little".

Motivational experience, all users recommended others use VR because of something new, easy to use, interesting, etc. We can be play gamelan anywhere and don't need to have gamelan. The use of VR gamelan Saron was very easy and interesting to use, especially for the expensive price of gamelan and the ingredients that make it difficult to find. There were 5 participants who suggested that there should be a haptic feature and holding the bar after being hit that called "pathet". One participant also suggested that there should be a complete tutorial to use VR gamelan Saron because if users have never used gamelan, they can more easily understand how to play it.

3.4. Discussion

The results of the SUS score using the controllers and hand tracking were significantly different from the p-value. From the results, the average score of sus showed that the VR controllers was higher than the VR hand tracking. This result was consistent with the interviews: using push-button was more accessible to command than hand gestures. While the advantage of hand tracking was that it looked more realistic when playing. The accuracy of the hand tracking was not perfect, and it needed to improve its accuracy and response. Sometimes hand gesture detection was not stable and detached. It caused the USEQ scores of hand tracking has lower than the controllers. However, from the interview results, participants gave some feedback for the evaluation of VR gamelan Saron.

3.5. Limitation and Recommendation

This study focuses on the comparison between hand tracking and controllers. According to one participant, the provision of features such as haptic and more complete tutorials makes the application more useful but VR hand tracking can't provide the haptic features in its use. That is one of the advantages using VR controllers. For further development, maybe gamelan can be made a multiplayer game so that the game does not only use Saron. More stable hand gestures are needed.

4. Conclusions

From the VR gamelan Saron case study, the SUS score was significantly different. It showed that users were more satisfied with using the controllers than hand tracking. However, for the USEQ scores of the two groups, there was no significantly different in the use of hand tracking and controllers. Using controllers was more accessible to command than hand gestures, while hand gesture detection was not stable and detached. The interview results revealed that VR gamelan Saron is a new and interesting innovation to play, so for future, development factors that affect the functionality and usability suggested by users are needed so that it can increase functionality and provide more realistic interaction.

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