ORIGINAL ARTICLE

An Investigation to Understand Spatial Ability Towards Emotional Engagement in an Immersive Virtual Reality Application

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ABSTRACT

Introduction: IImmersive Virtual Reality (IVR) is a computer-generated world where users can immerse using Head-mounted devices (HMD), but different spatial ability groups show different performance when engaged virtual reality. The VR application of the solar system roller-coaster tour develop by DrashVR LLC downloaded from Google Play used for the study. It aims to study spatial ability group's viewing techniques related to emotional engagement toward IVR. **Methods:** The study employed a qualitative research design with triangulation method to administer a spatial ability test before IVR sessions to determine low spatial (0-15 score) and high spatial (16-30 score) groups. Observations of 30 participants were made and conduct semi-structured interviews after each IVR session. **Results:** 23% of high spatial and 10% low spatial group used an aggressive viewing technique. While 33% of high spatial and 34% of low spatial using less aggressive and static viewing techniques restricted view less than 180 degrees to avoid unpleasant feeling. Both groups reported cybersickness after an average time of 5 minutes for low spatial and 7 minutes for high spatial. High spatial counter cybersickness by focus on visual elements to immersed and sustain attention while low spatial focus on the negative feeling that rip out enjoyment. 70% of high and low spatial with positive emotion engagement could sustain enjoyment due to motivated to continue VR tour despite having cybersickness. **Conclusion:** : Different spatial abilities displayed unique viewing techniques and emotional engagement to counter the unpleasant effects. The result significant when these groups of spatial using IVR as treatment.

Keywords: Virtual reality, High spatial, Low spatial, Viewing technique, Cybersickness

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INTRODUCTION

Immersive Virtual Reality (IVR)

From gaming to education, virtual reality (VR) helps us to discover a new realm which allows us to create, build, and customise our reality with a persistence, despite its physics and laws (1). In entering this hidden realm, there are three types of VR, namely: 1) non-immersive or desktop VR, which is presented on the computer or mobile phone screen; 2) semi-immersive VR, which employs large screens or multiple-monitor displays; and 3) full immersive VR (IVR), which employs head-mounted display devices (HMD) (2). Usually, VR content or applications are developed for gaming, training, and entertainment purposes. Recently, the technology blog Futurism (3) has named VR as a 'dead family reunion', whereby a mother reunites with her late child through an IVR combined with Artificial Intelligence (AI). For IVR, HMD is needed, and several types are available such as cable type HMD, which need to relate to the computer or game console (e.g. Playstation VR and HTC Vive). Another type of HMD is the on-the-go kind with a simplified design; it is smaller, lighter, and free of cables, such as Samsung VR, Google Cardboard, and inexpensive Original equipment manufacturer (OEM) HMD.

However, IVR often causes cybersickness; disorientation, nausea, dizziness, wanting to vomit, and headache (4). These are caused by a conflict between the visual and sensors, which gives fake self-movement in the virtual environment, lagging visual presentation, a visual presentation that consistently goes upside down, and a swift transition between the frame and camera movement that does not tally with participant's view (5). Therefore, cybersickness can be reduced by more practice, which will allow the participants to become more familiar with the virtual environment and provide a fully immersive system by providing visual, hearing, and haptic stimulations. These can help one to increase their immersion and emotional engagement towards the virtual environment (6).

Spatial Ability
When issues happen at the production site, engineers can observe and solve the problem by calculating the distance, seeing the mechanical part rotation, and figuring out how the machine runs. These are only by looking and visualising it in their heads: this is called the spatial ability (7). It is a standard cognitive skill set that helps the professionals in several fields such as engineering, technology, science, and mathematics to understand, connect, and remember the spatial relation between objects (8).

There are four types of spatial abilities (9). The first ability namely as Mental Folding, the ability to mentally rotate two dimensions (2D) / three-dimension (3D) objects. Mental Rotation is the ability to fold objects mentally. Spatial Visualisation, able to recognise the spatial relations of the objects, features, position, and motion. Spatial Perception, which allows one to mentally locate, identify, and estimate the distances and movements of the visual elements altogether.

Spatial ability can also be defined by high or low spatial ability. Whereby high spatial ability describes one being able to use spatial abilities very well compared to low spatial ability, which is used minimally in order to get excellent performance for specific tasks or jobs. For example, low spatial people have poor spatial Visualisation compared to high spatial people as the latter can perceive visual cues accurately, remember them very well, and manipulate them to get better performance. Knowing one's spatial ability is useful to determine their cognitive speciality in order to confront problems and make ethical decision-making (10).

High spatial ability participants can improve their skills when using non-IVR (11). However, Green and Seitz (12) have added that non-IVR is enough to facilitate and enhance problem-solving skills, as well as focus on activities for spatial ability tasks. It supported by Dede (13), who reported that VR could develop visual-spatial skills and spatial Visualisation by involving mental rotation skills and completing complex tasks.

Emotional Engagement
Emotion is a cognitive process that is stimulated by the environment, memory or personal experiences. It plays a significant role in the judgment and responses, as well as influencing a behaviour (14). It can also refer to the presence of emotions, such as joy, interest, amazement, awe, excitement, surprise, anticipation, interest, fear, and confusion. All engagement happens when the Perception, imagination, or memory is triggered by specific events happening in the surroundings or mental state (15).

Furthermore, audiovisual cues from the surrounding can affect motor behaviour and trigger emotional engagement. For example, one will dance when they hear certain music or feel something when hearing a disturbing or eerie sound (16). Therefore, IVR can give audiovisual stimulation in order to affect the emotional engagement. The use of the VR application can deliver immersive experiences that trigger emotional responses (17) through its visual presentation. Therefore, it is often used as a therapy (18) and treatment for Post-Traumatic Stress Disorder (PTSD), Pathological Grief (PG), or Adjustment Disorders (AD) (19). However, when virtual reality fails to trigger the right emotion and creates fear or threatening stimulations (20), it will lead to incomplete information reception and the objective of virtual reality sessions can become void.

Problem Statement
The spatial ability affects the information processing and learning ability of high spatial ability students, who report better skills achievements when using non-immersive or semi-immersive VR methods (11) but not immersive virtual reality (IVR). Meanwhile, the low spatial ability can be improved by using VR technology (9). However, Green and Seitz (12) have suggested that non-IVR is enough to facilitate the information process and help to enhance spatial ability. In contrast, non-IVR lacks the empowerment to immerse the participants, unlike IVR, that allows them to promote emotional engagement and facilitate information transfer more effective than non-IVR (14,21). Therefore, the purpose of this study is to study the difference between high and low spatial reactions according to their viewing techniques and anticipation of emotional engagement towards IVR application.

MATERIALS AND METHODS

Thirty healthy participants of 15 females and 15 males ranging between 22 and 32 years of age were tested with Differential Aptitude Battery Test Set (22). The result revealed 13 low spatial participants with a score below the mean (below 15) and 17 high spatial ability participants with a score higher than the mean (above 16).

Research Method and Instrument
This research employed a qualitative design and employs triangulation method that consists of a questionnaire to define high and low spatial abilities group (Fig. 1), observation while the participants in engaging with IVR experiences (Fig. 2) and interview session after IVR tour. Therefore, 30 students were tested for their spatial ability using the Differential Aptitude Battery Test Set (22) as shown by Figure 1. Adopted from the Differential Aptitude Battery Test (22), it consists of 30 items presented in two-dimensional folding patterns. It requires mental manipulation in the form of three-dimensional visualisation skills to solve and obtain the

correct answers, from a total of 30 questions, high spatial defined by above the mean value of 15. In contrast, scores below the mean (i.e. 14 and below) are defined as low spatial.

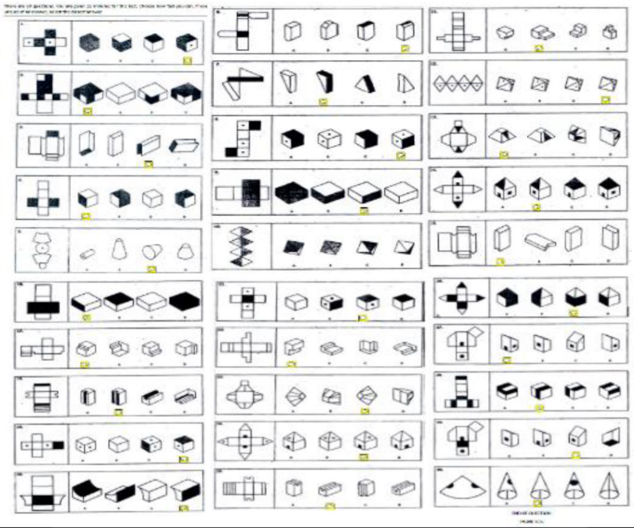

Figure 1 : Spatial test adopted from Space Relations Test that is taken from Differential Aptitude Test Bennett, Seashore & Wesman , 1972). Aptitude Test is a test battery that contains several cognitive tests, and one of the tests are Space Relations test to evaluate the spatial ability of the participants.

Figure 2 : The participants experience their Titan of Space VR tour with different viewing technique, feeling and condition according to their ease of use of the VR system. Participants with different spatial ability show different reaction toward their emotional engagement and how they react with the ease of use of the tools also viewing techniques.

After that, the participants were given a Titans of Space mobile application developed by DrashVR LLC and can be downloaded for free from Google PlayStore. The VR tour consists of 15–30 minutes according to their viewing technique. The participants verbal and physical expression recorded and observed. They might take a break, pause, or rest while having the VR tour. The VR application used the Samsung Gear VR HMD device with an accompanying smartphone. Figure 2 shown that Titans of Space is a short guided tour of the planets and a few stars in virtual reality, where the participants can set their roller-coaster type tour either automatically or by themselves.

Along with the IVR tour, there is a small screen inside IVR contents. It gives information about the celestial bodies, as well as showing the percentage of the overall VR tour. It allows the feature of the game resume if the participants need to pause or take a short break. However, the free version only gives a short tour of around 15–30 minutes from an entire 50-minute-long tour of the paid version, with inclusion narration and English subtitle. (Fig. 3)

In this study, the participants could express their feelings while having the tour, including their verbal and physical expression that involve head body movement. The interaction with surround was observed and recorded, as shown in Figure 3. Then, this was followed by the semi-structured interview sessions (Fig. 4), which covered: the viewing techniques, and the emotional engagement of the VR system. The viewing techniques consisted of how they wore the handle and used the HMD, as well as others related to the ease of use of the VR system. It involved the physical head and body movements. It also involves cursor command. Other elements are, it covered the assimilation of 360-degree of spreading visual presentation in the form of looking up and down, turning left and right, performing 180 degree turns to look back, what they saw in the VR application, and other questions related to viewing techniques. Then, the emotional engagement towards the visual, sound, and VR system consisted of questions like their feelings before and after wearing the HMD, their feelings before and after the VR tour, and other related to emotional. All interview sessions were recorded, and the interviews were transcribed verbatim in the native Malaysian language.

Figure 3 : Titan of Space VR application created by DrashVR LLC that can be download free from Google Play store. Titan of Space one of space education application can be download free for PC and android smartphone that can allow the user to learn about space with immersive virtual reality or by using desktop type PC.

Semi structured interview VR protocol

Name: ____________________
Spatial Group: □ High □ Low
Gender: □ Male □ Female

1- The ease of use of HMD and VR System

- **Effects of disorientation and Nauseousness.**
  - *Apakah perasaan anda semasa memakai HMD dan mula-mula mengikuti aplikasi ini?*
  - *Berapa lama anda mengalami perasaan ini?*
  - *Bagaimana anda mengatasi perasaan ini?*
  - *Ada Lagi tak perasaan lain yang anda alami?*
  - *Berapa lama anda mengalami perasaan ini?*
  - *Bagaimana anda mengatasi perasaan ini?*
  - *Ada lagi yang anda mahu kongsikan dengan saya?*
- **Learn-ability** (the capability of a application to enable the user to learn how to use it)
  - *Anda tahu mengunakan HMD?*
  - *Apa yang anda lakukan dengan HMD ini?*
  - *Apa yang anda lakukan untuk melihat visual VR menerusi aplikasi ini?*
  - *Berapa lama anda mampu mengunakan HMD untuk mengikuti aplikasi ini?*
  - *Apa yang anda kawal semasa mengikuti aplikasi ini?*
  - *Bagaimana anda mengawalnya?*
  - *Apa yang anda lihat semasa proses kawalan itu di dalam aplikasi ini?*
- **Effectiveness**
  - *Adakah anda berasa senang dengan pengunaan HMD ini?*
  - *Jika anda berasa senang, boleh terangkan kenapa*
  - *Jika anda berasa tidak senang, boleh terangkan kenapa*
  - *Adakah anda berasa senang dengan pengunaan aplikasi ini?*
  - *Jika anda berasa senang, boleh terangkan kenapa*
  - *Jika anda berasa tidak senang, boleh terangkan kenapa*
- **Errors**
  - *Adakah terdapat apa-apa keganjilan semasa mengunakan HMD?*
  - *Andai ada, kenapa dan di mana keganjilan itu terjadi*
  - *Boleh terangkan lagi kenapa ianya berlaku pada pendapat anda*
  - *Adakah terdapat sebarang keganjilan berlaku semasa mengikuti aplikasi ini?*
  - *Andai ada, kenapa dan dimana ketidakpuasan itu terjadi*
  - *Boleh terangkan lagi kenapa ianya berlaku pada pendapat anda*
- **Satisfaction**
  - *Adakah terdapat apa-apa perasaan semasa mengunakan HMD?*
  - *Andai ada, kenapa dan dimana kesenagan itu terjadi*
  - *Boleh terangkan lanjut mengenainya*
  - *Adakah terdapat apa-apa perasaan semasa mengikuti aplikasi ini?*
  - *Andai ada, kenapa dan dimana kesenagan itu terjadi*
  - *Boleh terangkan lanjut mengenainya*

2- Viewing techniques to as defined by head movements and cursor commands

- Assimilation of 360 degree, looking up and down, turning left and right, turns to look at bac considered as **AGGRESSIVE**
- Assimilation of 180 degree, looking up and down, turning left and right, turns to look at back considered as **LESS AGGRESSIVE**
- Assimilation of less than 180 degree, limited up and down, turning left and right, don not to turns to look at back considered as **STATIC**
  - *Apakah cara untuk anda melihat objek visual di sekeliling anda?*
  - *Bagaimana anda melihat objek visual tersebut?*
  - *Anda mengawal penglihatan anda dengan cara kawalan yang bagaimana?*
  - *Berapa kerap anda melihatnya?*
  - *Apa bahagian paparan yang menarik minat perhatian anda?*
  - *Bagaimana anda melihat objek tersebut?*
  - *Berapa lama anda melihat objek itu?*
  - *Di bahagian mana yang anda suka tengok?*
  - *Di bahagian mana yang anda tidak suka tengok?*
  - *Anda melihat objek tersebut dengan cara kawalan yang bagaimana?*
  - *Apa yang terjadi bila anda lakukan kawalan itu?*
  - *Apa objek visual yang masih bermain di fikiran anda ketika ini?*

Figure 4 : The example of semi-structured interview questions. This semi-structured interview occurs after the IVR session and taken 10-30 minute for each interview session.

Table 1 : The list of High and low Spatial participants out of 30 participants

No.	spatial	Gender	Age	Physical Behaviour	body movement	head movement	observation note	Emotion Indicator	visual engagement time duration (before report fatigue) - minutes
					HIGH SPATIAL GROUP				
1	23	m	23-27	static	limit	limit	anxiety	negative	4
2	23	m	28-32	mild	limit	not limit	calm, a bit dizzy	positive	8
3	24	m	23-27	static	limit	limit	anxiety, sleepy	negative	5
4	24	f	28-32	mild	limit	not limit	calm, sleepy	positive	7
5	24	m	28-32	aggressive	not limit	not limit	excited, visual fatigue	positive	8
6	25	m	28-32	aggressive	not limit	not limit	excited, visual fatigue	positive	9
7	25	m	28-32	mild	limit	not limit	calm, visual fatigue	positive	8
8	25	m	28-32	aggressive	not limit	not limit	excited, visual fatigue	positive	9
9	25	f	23-27	aggressive	not limit	not limit	turn around a lot, body imbalance	positive	9
10	26	f	28-32	mild	limit	not limit	calm, a bit sleepy	positive	8
11	26	f	23-27	static	limit	limit	calm, sleepy	negative	5
12	27	f	28-32	aggressive	not limit	not limit	excited, turn around a lot, cybersickness	positive	9
13	27	f	23-27	static	limit	limit	panic, anxiety, dizzy	negative	5
14	28	m	28-32	mild	limit	not limit	excited, body imbalance	positive	8
15	28	m	28-32	aggressive	not limit	not limit	calm, not use stripe, calm, turn around a lot	positive	8
16	28	f	23-27	aggressive	not limit	not limit	excited, dislike HMD stripe, visual fatigue	positive	9
17	28	f	28-32	mild	limit	not limit	anxiety, want to vomit	positive	8
					LOW SPATIAL GROUP				
1	9	f	23-27	static	limit	limit	anxiety, panic, hold the chair, cybersickness	negative	5
2	13	f	23-27	aggressive	not limit	not limit	excited, visual fatigue	positive	8
3	14	f	28-32	static	limit	limit	panic, not move want to avoid nausea, cybersickness	negative	4
4	14	m	28-32	static	limit	limit	anxiety, did not move a lot, cybersickness	negative	3
5	14	f	28-32	static	limit	limit	anxiety, did not move a lot, cybersickness	negative	4
6	16	f	23-27	mild	limit	not limit	anxiety, body imbalance, dizzy	positive	6
7	16	m	23-27	mild	limit	not limit	excited, dizzy	positive	6
8	16	m	28-32	mild	limit	not limit	did not use stripe, calm	positive	6
9	15	m	28-32	static	limit	limit	panic, anxiety	negative	4
10	13	f	23-27	mild	limited	not limit	anxiety, body imbalance	positive	4
11	14	m	23-27	aggressive	not limit	not limit	excited, turn around a lot, body imbalance	positive	7
12	15	m	28-32	aggressive	not limit	not limit	excited, turn around a lot, body imbalance	positive	7
13	13	f	28-32	mild	limit	not limit	calm, body imbalance	positive	6

Table II : The list of physical movement according to spatial abilites groups and head body movement to enjoy the IVR content.

Physical Behaviour From Total Participants	Low Spatial Participants	Low Spatial %	High Spatial Participants	High Spatial %	Total %
Static	5	17%	4	13%	30%
Less Aggressive	5	17%	6	20%	37%
Aggressive	3	10%	7	23%	33%

Note: Physical behaviour according to static, less aggressive and aggressive head body movement

Head Movement	Low Spatial Participants	Low Spatial %	High Spatial Participants	High Spatial %	Total Participants
Limit	5	38%	4	24%	9
Not Limit	8	62%	13	76%	21
Total	13	100%	17	100%	30

Note: Physical behaviour according to head movement

Body Movement	Low Spatial Participants	Low Spatial %	High Spatial Participants	High Spatial %	Total Participants
Limit	10	77%	10	59%	20
Not Limit	3	23%	7	41%	10
Total	13	100%	17	100%	30

Note: Physical behaviour according to body movement

RESULTS

From total 30 participants, 13 have low spatial ability resulted below 15 score and other 17 have high spatial ability after resulted above 16 score of Differential Aptitude Battery Test Set (22) (Table I).

Types of Viewing Techniques Used as Defined by Head and Body Movement, And Cursor Command towards VR content

70% of low and high spatial ability participants reported that the HMD was easy and comfortable to wear, and the instructions were easy to follow and would strip it tightly to feel more confident. Other 30% did not use the head strip due to it being uncomfortable for them. Both groups reported that the text in virtual content was blurry and needed to bend the neck a lot while reading the context at the in-app monitor screen. They also did not use the cursor command much to pause or zoom on the presentations but relied mainly on head movements to search for inputs. It is the main reason of aggressive, less aggressive and static physical behaviour when engaging IVR content (Table II).

Table III : 70% or 21 participant from both groups feeling positive while the other 30% was feeling unpleasant toward IVR tour.

Emotional Engagement According The Groups

	Low Spatial Participants	%	High Spatial Participants	Total %
Negative	5	38%	4	24%
Positive	8	62%	13	76%
Total Participant (%)	13	100%	17	100%

Note: Total Participants And Percentage According To The Spatial Abilities' Groups

Emotional Engagement From Total Participants

	Low Spatial Participants	Low Spatial % From Total Participants	High Spatial Participants	High Spatial % From Total Participants	Total Participants	Total %
Negative	5	17%	4	13%	9	30%
Positive	8	27%	13	43%	21	70%
Total Participant (%)	13	44%	17	56%	30	100%

Note: Total Participants And Percentage According To Emotional Behaviour (Positive Or Negative Emotion Engagement)

In head movement table, there are 13 participants of high spatial participants and 8 participants of low spatial used extensive head movements by looking up and down, left-right, bending their necks a lot and bending their hand as an expression to engaging with the VR objects while enjoying the IVR tour. They also frequently moved their body by spinning 360 degrees in their chairs and swung in their seats to explore the 360-degree view as they appreciated the stunning visual elements, even though the actions caused some motion sickness. The other 4 participants of high spatial and 5 participants of low spatial participants used static viewing technique It mostly involving looking up and down, and right and left from 90 to 180-degree viewpoints only to avoid aggressive head movement in order to reduce motion sickness along the VR tour. Low spatial participants reported that they only wanted to focus on enjoying through VR tour.

In Body Movement table, there are 10 participants of high and low spatial participants used limited body movement of 180-degree movement. It different with 7 of high and 3 of low spatial that use 360-degree of turn around body movement involving spreading their hands, legs and stand up also to sit down repetitively when engaging IVR tour.

However, both groups agreed that the good feeling ended less than halfway through the tour because of motion sickness. Low spatial reported that they feel cybersickness, dry eyes, body imbalance, and nausea after 3-8 minutes of IVR session started, while high spatial group reported after 4-9 minutes. Seven high spatial and three low spatial from 30 participants can maintain their focus, even using aggressive physical behavior to cause unpleasant side effects. Based on the interview, this behavior due to wanting to keep a sense of presence. By gender-based, it showed the high spatial males were more focused on the visual elements and wanted to have aggressive haptic responses to have more realistic experiences. In contrast, the female high and low spatial participants focused on audio input due to comfortable VR experiences. Both groups agreed that Samsung Gear VR was comfortable to wear as it was light, cable-less, and user-friendly.

Emotional Engagement with VR Content

70% of total participants reported feeling excitement, amazement, and joy throughout the VR tour because they able to get immerse with VR tour even reported have cybersickness. While 30% feeling unpleasant when engaging IVR content (table III). They reported felt anxiety, panic, and scared by the symptoms of cybersickness and un-able to focus on the enjoyment of the VR tour. Seven participants from 17 participants (23%) of high spatial and three from 13 participants (10%) low spatial group showed aggressive physical behavior during the VR tour, they quickly immersed into the visual presentation and were than audio elements. They were more focused on the visual elements, such as the distance, size, texture, and wonderment of the celestial bodies.

While 10 out of 13 participants from the low spatial group using static and less aggressive viewing techniques, they only focused on audio elements. They also focus on negative feelings rather than enjoyment. They reported gripping the chair and limiting their body movement due to feeling the floating sensation, anxiety, and excitement at the same time. Therefore, despite being offered productive of virtual celestial bodies such as moons, asteroid, planets, and immersive background sound, the participants were unable to sustain maximum attention until the end of the tour, which was only 15 minutes in duration out of the 30-minute total of IVR tour.

According to the table I, it happens due to the cybersickness that occurs 3-8 minutes after the IVR session started for low spatial groups and 4-9 minutes for high spatial groups. From the interview session, the high spatial group shared their thoughts of wanting to enhance the VR application's excitement. It consists of adding more features such as zooming onto the planet surfaces, the ability to land on the planet surfaces, and manipulating the objects in their view. They wanted to gain more information through the tour. Meanwhile, low spatial only wanted to enjoy the tour as any regular physical roller-coaster without concerning additional features to enhance IVR content's emotional engagement.

DISCUSSION

This study aimed to understand about high and low spatial abilities towards the emotional engagement in an IVR application by investigating their viewing techniques. Nowadays, VR is used as an educational method whereby some situations are dangerous and impossible to be attempted in the real world (5). An example is an act of observing the celestial bodies closely in order to learn more about it, which is impossible. Nevertheless, virtual reality allows the impossible to be possible. In this study, Samsung Gear VR HMD was used, and the participants could control the application by using gesture controls found at the side of the HMD or pinpoint their view to a point visually. From the recorded observations and semi-structured interviews, both groups relied mainly on head movements to search for inputs. They rarely used the touchpad at the side of the HMD to control the visual interface.

Therefore, the HMD is enough to stimulate audiovisual stimulations and affect the emotional engagement (19) which is essential to influence the actions taken by the participants to understand, perceive, and react to the surrounding. Therefore, both spatial ability groups reported high enthusiasm in the early stages of the VR tour, while mild nausea, discomfort, tiredness, and fatigue were reported halfway through. These are due to the simulation sickness caused by the roller-coaster type of movements produced by an unusual combination of "dolly" and "swing" functions of the camera in the dark at varying speeds in the tested VR tour. Unsurprisingly, both groups had motion sickness as support by Jeong et al. (5). The study said, IVR experiences often produce nausea, dizziness, disorientation, eye strain, and headaches (4). If IVR fails to stimulate the emotion and immersion of the participants, the chance of motion sickness will be increased when using HMD. In turn, this will provoke the undesirable effects of motion sickness (14), and the objective of the training or simulation will fail (16).

In terms of the viewing techniques, each group performed different head and body movements; for instance, aggressive physical behaviour indicates aggressive. It also involved extensive head body movements. While the less aggressive behaviour indicates used limited head and body movements consist of 180-degree view, slow head body movement and rarely express their emotion through body action while engaging the IVR content. High spatial participants reported paying more focus on the visual elements in the VR content, were engaged in exploring by covering the full 360-degree view, and wanted more interactive elements to gain more knowledge from the VR tour. This finding also showed that the high spatial participants were easily distracted while engaging in the VR tour due to them wanting to be more immersed in the environment and try to gain information more than low spatial groups. To help high spatial in order to gain more engagement and interactivity toward IVR, the level of immersion and realism of virtual reality content should be increase especially by using 360-degree VR (14, 23).
Low spatial group reported were more engaged in the game for enjoyment purposes and were impressed by the grandness of the objects for an immersive experience in dealing with the visual and audio elements in order to focus and sustain their viewing from distracted by cybersickness. Surprisingly, the low spatial group was able to recognise the objects and space in more detail as they could engage with their emotions and enhance the presence within the VR environment. As per the interview, high spatial ability participants outperformed the low spatial ability participants when asking about the celestial objects in IVR tour. This finding supported by Mania and Chalmers (24) where they favoured the high spatial ability participants as they were more attentive to the details presented and collecting facts from virtual environment rather than low spatial (10).

As per the report, 43% of the high spatial and 27% of low spatial participants were able to sustain their focus before feeling the fatigue and cybersickness as they were able to immerse with the virtual content. Presence affected by their emotional engagement and enthusiasm in wanting to interact with VR environment: this is why their viewing technique is aggressive and extensive (25). In contrast, the limited viewing techniques resulted in the lack of emotional engagement, causing them to be unable to immerse towards the VR presentation. The immersion level determines the attention span of the participants, which is affected by motion sickness symptoms such as fatigue and cybersickness, thereby ripping away the enjoyment of virtual simulation (14). Moreover, the 21 participants of both groups were more excited and able to sustain their engagement with IVR content. Out of 30 participants, nine were more passive and had an unpleasant feeling to interact with the visual environment. These happen due to nausea, cybersickness, body imbalance, dizziness, and dry eyes distracted participants from enjoying the rest of the full IVR tour. Therefore, these distractions could ruin their attention span and immersion towards VR environment. This finding may help to understand that viewing techniques of different spatial abilities can differ between different extents of emotion when engaging in the immersive virtual environment.

CONCLUSION

This study found that 70% of both groups reported positive emotional engagement, even having unpleasant feelings such as cybersickness. They were motivated to continue VR tour due to immerse within the VR tour. 33% of high and low spatial participants with the aggressive viewing technique can sustain their attention span by focus on interactivity and engaging with IVR audiovisual elements. While 67% of the rest only limited their viewing technique due to felt demotivated to continue the VR tour caused by cybersickness. The spatial group's report shows the high spatial counter cybersickness by focus on visual elements and interactivity to get more immersed while sustain their attention span. Low spatial otherwise just enjoy the moment and want to gain the experiences. Both groups reported high enthusiasm in the early stages of the tour. However, they reported cybersickness after an average time of 5 minutes for low spatial and 7 minutes for high spatial ability groups. It indicated a high spatial able to sustain attention span more than low spatial. The study showed that different spatial abilities displayed unique viewing techniques and emotional engagement levels to accept the unpleasant feeling and sustain their enjoyment while avoiding the unpleasant effects of IVR presentation. This finding is significant because it focuses on the relationship between viewing techniques consisting of head and body movement toward emotional engagement when interacting with immersive virtual reality according to high and low spatial groups. It can help medical practitioners, scientists, VR developers, and researchers to evaluate emotion engagement according to high and low spatial groups. More studies are recommended using different virtual reality types (e.g., desktop type, semi-immersive, and low- cost vs. high-cost IVR), use a longer duration of engagement, and use 360-degree VR for the same purpose.

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