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An evaluation of intelligent and immersive digital applications in eliciting cognitive states in humans through the utilization of Emotiv Insight

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ABSTRACT

The amalgamation of Virtual Reality (VR) and Artificial Intelligence (AI) results in the development of many promising applications that are helpful for society in many aspects. This research was done to study the effect of immersive and non-immersive applications on user's psychological parameters. In this paper, an intelligent, interactive, and immersive digital application was designed, and the various psychological parameters of users while using the application were analyzed through the brain computer interactive device, Emotiv. The impact of these robust and immersive applications on the emotions of human beings was analyzed. According to the observations, the stress and relaxation levels are getting minimally affected, whereas the engagement levels are high for an immersive application rather than a non-immersive application. Hence, it can be concluded that immersive applications put users "in" the application environment and provide a near-realistic experience by blurring the line between the real and virtual worlds. Deeper immersion results from the increased sensation of presence, which in turn is helpful in increasing motivation and emotional investment.

- This paper demonstrates the implementation of the A* algorithm within the Unity 3D Game Engine to develop an intelligent digital application, fostering interactivity and depth.
- This paper explores the integration of VR technology to transform the digital application into an immersive and interactive experience, enhancing user engagement and realism.
- This paper investigates the utilization of the Emotiv Insight device to analyze cognitive parameters within both non-immersive AI-based and immersive AI & VR-based applications, providing insights into user experiences.

Specifications table

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Background

The term “Artificial Intelligence (AI)” combines the terms “artificial” and “intelligence,” signifying “man-made” and “thinking power,” respectively. Therefore, it can be explained as “a man-made thinking power.” We can also interpret AI as a branch of computer science that enables the creation of intelligent machines capable of human-like behavior, thought, and decision-making. John McCarthy, the father of the field, describes AI as “the science and engineering of creating intelligent machines, particularly intelligent computer programmers” [1]. In order to create intelligent software and systems, it is essential to first understand how the human brain works, as well as how people make decisions, learn, and collaborate to solve problems. Similarly, the technology that is also spreading rapidly throughout the world is Virtual Reality (VR) [2–3]. VR is a technology that immerses the user in a virtual world, far from the real world, yet elicits a sense of being in the real world. In the present research work, VR and AI technologies are used simultaneously to design and develop intelligent and interactive non-immersive and immersive applications [4].

Immersive technology has become popular in the field of Computer Science (CSE) [5]. Immersive technology is categorized into VR, Augmented Reality (AR), and Mixed Reality (MR) [6,7]. VR is made available to a global audience through Steven Spielberg’s adaptation of Ernest Cline’s best-selling novel “Ready Player One” in a cinema. VR technology has been around since 1960, but it hasn’t been widely adopted because of the expensive and low-quality equipment [8]. The technology has advanced now and experienced a second spring with the introduction of low-cost and high-quality appliances like Head-Mounted Displays (HMDs). HMDs are eyeglasses with small projection screens or other displays that can be attached to headgear or helmets [9]. One kind of HMD that overlays a picture over the user’s perception of the outside world instead of blocking it is called a heads-display [9]. Some HMDs incorporate motion sensors to detect direction and movement and also serve as the boundary for VR applications [10,11].

HMDs play a vital role in experiencing immersive digital applications. The digital application is a computer-based, interactive, rule-governed system. The word “interactivity” means the need for a continuous flow of communication between the player and the application [12]. Computer applications engage and inspire people worldwide. The number of people playing digital applications has also increased dramatically. The NPD Group states that 6 percent more Americans play digital applications than they did the year before (73 %) [13]. According to statistics, there are currently over 2.6 billion video game players worldwide, with that number predicted to reach over 3 billion by 2023 [13]. Research papers demonstrate that the integration of innovation, social media, and internet technology has partially addressed the numerous obstacles of the COVID-19 pandemic. These digital technologies have been extremely important for economic, healthcare, educational, and communication activities. They have also helped people be resilient and adapt during this global crisis [14]. Digital applications that are developed with AI technology are more intelligent, behave more like real-world applications, and attract more users. In a similar vein, this paper use Emotiv Insight, a 5-channel brain computer interface device, to examine the user’s psychological parameters as they experience the intelligent and interactive non-immersive and immersive intelligent applications [15]. The parameters that are considered for this study are Arousal (Excitement), Valence (Interest), Frustration (Stress), Engagement, Focus (Attention) and Relaxation (Meditation). This paper presents the development phase of an intelligent and interactive non-immersive and immersive applications based on AI & VR technologies. After development, analysis of the user’s cognitive state has been done by using the Emotiv Insight 5-channel device.

The subsequent sections of the article are organized in the following manner: After examining the related work in Section II, Section III provides a comprehensive explanation of the method details required to design and develop the non-immersive and immersive applications. Section IV emphasizes the importance of VR and AI by providing clear and illustrative examples. Section V covers the processes involved in developing and deploying the applications, while Section VI focuses on the analysis of data collected via the Emotiv Insight program. The findings obtained from the analysis conducted in Section VI are presented in Section VII, which ultimately leads to the conclusion depicted in Section VIII of the paper.

Related work

The research on interactive technology in VR and AI together is growing exponentially in this digital era. Many researchers are working on this topic, developing intelligent and immersive applications that are very useful for our society. This section of the paper briefly presents researcher’s works in this field.

The Lynch et al. [14], research paper demonstrates how the integration of social media, innovation and internet technologies has been contributory in addressing various issues posed by the COVID-19 pandemic. These digital tools have played important roles in healthcare, education, economics activities and communication, contributing to adaption and resilience during this global crisis.

According to Ende et al. [16], AI is frequently included in VR, AR, and radiogenomics programming and technology because it can enhance the precision and effectiveness of radiological therapy and diagnosis planning. AI is becoming more and more used in radiology, even though it has numerous limits in the medical industry. This is because deep learning and machine learning are always evolving.

Chen et al. [17] developed an application using robots for English-language guided tours for training. It comprises VR and AI technologies to develop the contents of the tour and a 3-Dimensional (3D) virtual environment using Unity and an AI plug-in for programming. The robot acts as a tour guide for various places, and students can interact with it orally. The demonstration and testing of the robot were done for ten consecutive days. The result shows the effectiveness of teaching through robots. The participants acknowledged the role of robots in the learning process and showed a positive attitude. Hence, it can be used as an alternative learning opportunity for learners.

Xiaoxia Luo [18] examined how VR can help learners improve their English proficiency for business purposes. The study of mixed methodology illustrates that VR technology can be used to enhance English communication. The researcher concludes that AR and AR/VR can be educational tools in the future.

Xiaotao Wang [19] focuses on Machine Learning (ML) and VR technology-based college English learning and teaching approaches. The aim of the research is to improve the student's capacity to acquire English. Two groups participated in the study at the university: the experimental group and the control group. The experimental group used ML and VR-based applications for learning English, whereas the control group used conventional learning techniques with multimedia equipment to learn English. The result shows that ML and VR based teaching techniques genuinely increased learners' English level.

Yanrong Bao [20] looked at two very popular technologies, VR and AI, in an attempt to further the growth of Film and Television Animation (FTA) education. Initially, dynamic modeling technology, stereoscopic display, VR technology, and real-time 3D graphic modeling were combined to design the FTA teaching tools. As an auxiliary teaching aid, VR technology, along with 3D animation, is used to raise the quality of instruction in professional courses. The parameters, like classroom satisfaction, application effect, effect of professional curriculum, and quality evaluation, are analyzed and compared. The investigation revealed that the students in the VR technology group had improved by 81 %, 61 %, and 75 %, respectively, in terms of quality evaluation, teaching facilities, manner of instruction, and classroom atmosphere. With respect to the traditional approach, the satisfaction of learners is higher, and the rate of harvest is also greater.

Jiyong Lv., Xiangzhi Jiang, and Ang Jiang [21] illustrate the possibilities of using VR-based AI applications to train sports skills. They also discussed the use of VR and AI technologies together for tennis training, which is one of the most expert sports. Finally, they had to implement VR based on AI in the skills training of sports.

Yunxuan Wu [22] proposed a detection method for an art object using VR digital art media along with AI. The aim was to detect an object; a clustering idea and residual network-based object detection strategy were proposed. It also uses an algorithm like K-mean++ for performing clustering statistics on the datasets. The soft-NMS algorithm is employed in lieu of the NMS algorithm for post-processing the candidate's boxes. At last, researchers performed extensive experiments to verify the superiority of the proposed method.

The design and development of an AI and VR-based platform called PlumoVR, which aids in individualized surgical planning for pulmonary segmentectomy, is demonstrated by Sadeghi et al. Finally, it was proposed that future clinical exploration demonstrate its benefit in the clinical domain. Initially, the application was used on 10 eligible patients, and the results showed that both patient and surgeon had potential benefits [23].

Zingoni et al. [24] designed and developed the VRAIlexia project for teaching dyslexic students using innovative methods. The project's primary component is BESPECIAL, a software platform developed with the use of VR and AI. The platform is capable of understanding dyslexic students' issues and helping them with ad hoc digital help so that the difficulties they face in their studies can be reduced.

Method details

The tools and technologies employed for design and development of intelligent and interactive non-immersive and immersive applications are as follows:

- ***Searching algorithms*:**

One of the most crucial aspects of AI is search algorithms. Search methods are common approaches to solve issues like searching for the shortest path in AI [25,26]. These search techniques or algorithms are typically utilized by intelligent agents in AI to solve certain problems and deliver the best outcomes [27]. There are mainly three types of algorithms: deterministic algorithms, non-deterministic algorithms, and procedural generation algorithms [28]. The categorization of AI algorithms is shown in Fig. 1. This paper employs the AI heuristic algorithm to create an intelligent and interactive non-immersive and immersive digital application. Computer scientists Nils Nillson, Peter Hrat, and Bertran Raphael invented this algorithm in 1968 at Stanford, mimicking the way a human thinks and moves back and forth to achieve a goal. As an admissible algorithm, A* ensures the guarantee of an optimal solution though it is a little more complex than depth-first search and breadth-first search algorithms (Fig. 2).

- ***NavMesh***

Navigation Mesh, or NavMesh, is a Unity built-in feature. The A* algorithm uses it to further divide an environment into navigable areas for path finding. The method, originally known as "metamap," was developed for robotics applications in the mid-1980s. The NavMesh splits a model or environment into a sequence of polygons and allocates a cost to each of them. There are four tabs in the Unity navigation system: agents, areas, brakes, and objects.

An agent has four properties, such as names, radius, height, step height, and max slope. The size of the agent is defined by the cylinder.

The area tab is where we can find the cost of various NavNesh parts. The price is used by the A* algorithm to estimate the best path across the mesh from one node to another.

The bake tab turns into mesh in NavMesh. It has been done by dividing the mesh into numerous polygons and determining where the agent should be able to travel using the baked agent size. By default, humanoids are the only agents recognized by NavMesh. The data in the NavMesh can be set using the manual voxel setting. Before constructing the NavMesh, data structures called voxels will divide the environment. The larger the voxel size, the less accurate the NavMesh, and bigger the environment, more the mission

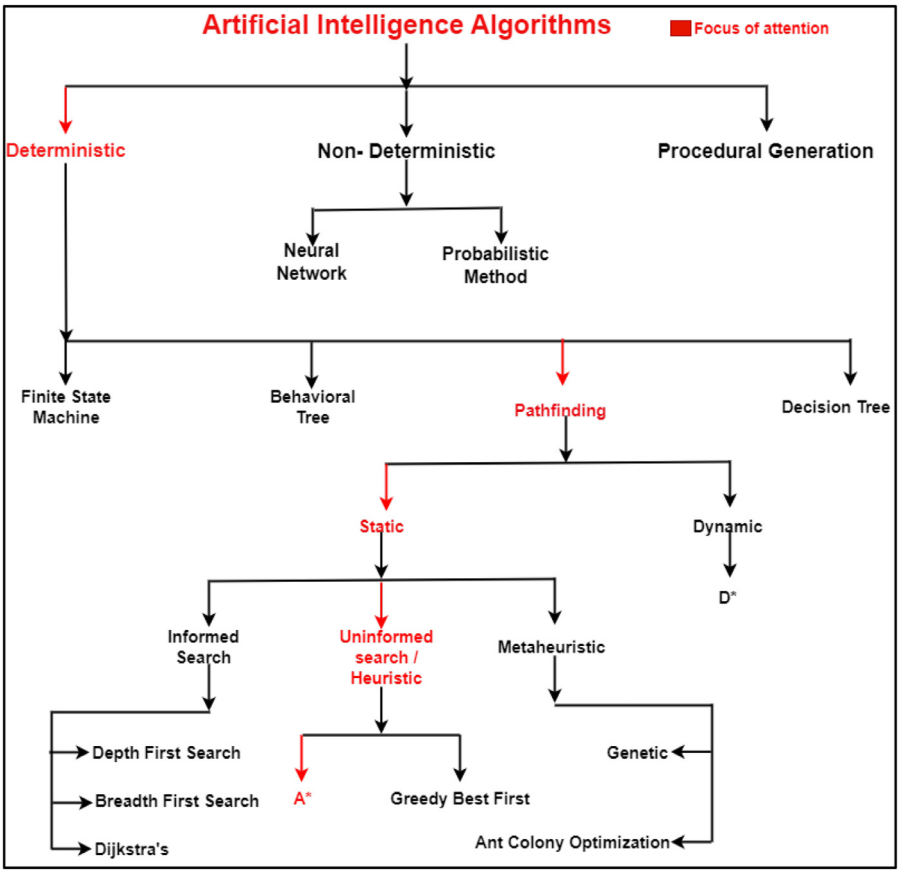

Fig. 1. The searching algorithms.

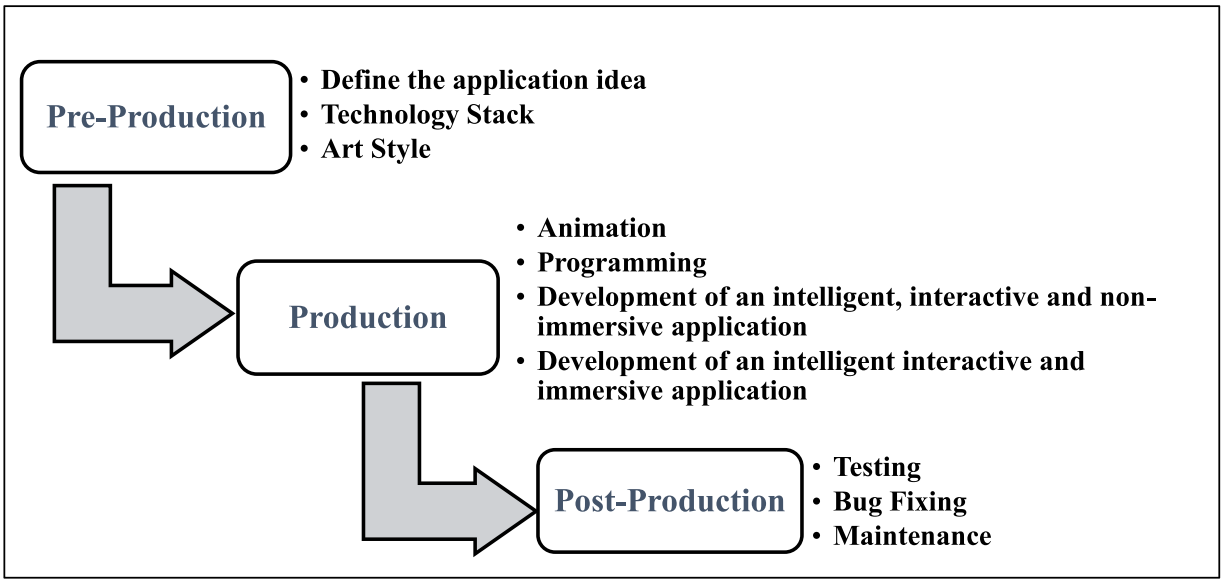

Fig. 2. The development phase.

will miss some of the mesh details. We actually set this value to 3 per agent radius, with 3 or 4 being the ideal values. The minimum region area allows us to remove sections of the mesh that were navigable but are too small to be of any use, and we don't want them included in the pathfinding. By increasing the minimum region area and rebaking, we can remove the small areas. When a NavMesh is generated for a bunch of meshes, it averages the height and can do things like turn stairs into slopes.

The object tab allows users to specify the part of scene to create the NavMesh as well as generate off-mesh links that allow transmission from one NavMesh to another.

NavMesh is a powerful approach to get Non Playing Character (NPC) moving with very little effort. With the help of NavMesh, all types of scenarios can be created, from patrols and crowds to traffic and flocks.

- ***Unity Game Engine***

CEO David Helgason defines Unity as "a toolset used to build applications, and it is the technology that executes the graphics, the audio, the physics, the interactions, and the networking" [28]. Unity 3D is an Integrated Development Environment (IDE) and game engine for developing interactive media, primarily video applications. Initially, Unity supported only Mac OS, but now it supports Windows operating systems and Android as well. It was developed using the C++ language. Knowledge of C#, C++ is required for scripting in Unity. Since it is user-friendly, many application developers use it when designing games. Designers use Unity to develop games such as Monument Valley, Pokémon Go, Beat sabre, Cuphead, and Call of Duty Mobile. Various immersive stimulators are also designed using Unity.

- ***Oculus Quest***

Oculus, a subsidiary of Facebook Technologies, developed the Oculus Quest, a VR headset. With the Oculus Quest, users can enjoy a complete VR experience right out of the box. There is no need for additional equipment or a complicated setup. Everything the user needs is conveniently built into the headset, from the display and processor to the motion tracking sensors. Due to its advanced tracking capabilities, users can move and interact within virtual environments with complete freedom, resulting in a greater sense of immersion and realism. With its high-resolution displays and integrated audio, the Quest offers an exceptional visual and auditory experience. In addition, the touch controllers provide a seamless and realistic way to interact with virtual environments, enhancing the gaming, entertainment, and social aspects of VR.

- ***Emotiv Insight***

The Human Computer Interface (HCI) area investigates the applied psychology of information processing that takes place during human-computer interaction; one way to do this is through the use of Brain Computer Interfaces (BCIs) device. This research uses the Emotiv Insight 5 channel as a BCI device. The EMOTIV Insight, a 5-channel EEG headset is used to monitor and record EEG signal data of user's. This headset has five electrodes, which match the number of channels. These electrodes amplify the weak synaptic signals they pick up from the scalp. These signals are transmitted to a computer, where the data is processed using Bluetooth 4.0 on Windows [29].

Importance of VR and AI

Recently, developers have primarily adopted VR and AI technologies to develop intelligent, interactive, and immersive applications. AI is described "as a program that, in an arbitrary world, will cope no worse than a human" by Dimiter Dobrev [1].

The ability of AI and VR to personalize people's experiences, assist in the data analysis of small and large datasets, and decrease workload [17]. Grand View Research estimates that the AI market was worth USD 93.5 billion in 2020 and would grow at an exponential rate of 38.1 % by 2030 [30]. In a similar vein, Markets & Markets predicted that the AI market would reach USD 309.6 billion by 2026, up from USD 58.3 billion in 2021. In contrast, Markets & Markets predicts that the VR market will reach USD 87 billion by 2030, up from its USD 21.83 billion valuation in 2021 [30]. Hence, there is an increasing trend towards combining these two technologies [31]. During the pandemic, AI and VR technology both experienced high demand, since companies were required to carry out their intelligent business operations virtually [32].

Although the field of combining VR and AI technologies is relatively rare, but still it continues to evolve. This paper uses AI and VR technologies to design and develop intelligent, interactive, non-immersive, and immersive applications. To convert the intelligent, interactive, and non-immersive application into an intelligent, interactive, and immersive application, an efficient HMD is required to be selected and configured in Unity game engine.

Development

- ***Phase 1: Pre-production***:

In this phase, the storyboard for the application idea is prepared. According to the application idea, technology needs to be chosen for development. The Unity Game Engine, version 2019.3.8f, is used to develop the AI & VR based intelligent, interactive, non-immersive and immersive applications. The optimal pathfinding algorithm A^* is fixed to be implemented on NPC for making the character intelligent. Finally, the animation style and visual effects are finalized.

- ***Phase 2: Production:***

The development and deployment processes for intelligent, interactive non-immersive application as well as intelligent, interactive and immersive application are demonstrated in this section.

Development of an intelligent, interactive, non-immersive digital application

Initially the assets like environments, animations, and NPC are created. Then the gameplay mechanics are implemented by using A* algorithm and interactive elements. To implement A* algorithm following steps are done:

Select all the item want to include into the mesh.

Click on Inspector, and then select the object. Now, from the static dropdown box, select the Navigation Static option.

Open the navigation window. The navigation window can be found under component navigation. Window->AI->Navigation Tab.

In Navigation tab click on Advanced->Bake

Select NPC then in the Inspector, Right Click->Add component->NavMesh Agent. UnityEngine.AI.NavAgent is known as an agent.

The code of A* algorithm is as follows:

Code 1: A*

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.AI; // Added since we're using a navmesh.

public class AI : MonoBehaviour
{
  // Variables to handle what we need to send through to our state.
  NavMeshAgent agent; // To store the NPC NavMeshAgent component.
  Animator anim;      // To store the Animator component.
  public Transform player; // To store the transform of the player. This will let the guard know where the player is,
    so it can face the player and know whether it should be shooting or chasing (depending on the distance).
  State currentState;
  void Start()
  {
    agent = this.GetComponent<NavMeshAgent>();      // Grab agents NavMeshAgent.
    anim = this.GetComponent<Animator>();       // Grab agents Animator component.
    currentState = new Idle(this.gameObject, agent, anim, player); // Create our first state.
  }
  void Update()
  {
    currentState = currentState.Process();      // Calls Process method to ensure correct state is set.
   }
}
```

The NPC is patrolling in an environment built in Unity, and when it sees the user, it starts shooting if its weight is more than 10 units; otherwise, it will stop shooting, as shown in Fig. 3.

The user will be able to chase the NPC character around the virtual environment by using the arrow keys on the keyboard. Fig. 4 displays few screenshots of the developed application. The game character is patrolling the environment, as shown in Fig. 4(a). When the character sees the NPC, it starts firing if the game character's mass is more than or equal to 10 units, as depicted in Fig. 4(b); otherwise, it doesn't fire, as shown in Fig. 4(c).

Development of intelligent, interactive and immersive digital application

The intelligent, interactive, and non-immersive application has been transformed into an intelligent, interactive, and immersive application by using VR technology. The use of Oculus Quest HMD helps to experience the immersive application. The controllers allow the user to move around the NPC character in a virtual environment. Some screenshots of the application are shown in Fig. 5.

- ***Phase 3: Post-Production***:

This stage encompasses the different tasks that follow application development and deployment. It involves building of the finished product as well as it also involves sustaining, growing, and occasionally expanding the application as it engages with the user and the outside environment.

Analysis using Emotiv Insight

The Emotiv Insight device is used to analyze the cognitive states of the user. The parameters considered for cognitive state analysis are excitement, interest, engagement, stress, and relaxation. Researchers can gain a thorough understanding of a person's mental condition in various situations by analyzing these affective and cognitive variables. Various domains, such as psychology, healthcare, educational technology, and Human-Computer Interaction (HCI), can benefit from this information. Quantifying these characteristics in a variety of ways, such as physiological sensors, self-report questionnaires, and behavioral observations, also enables multidimensional assessments of emotional experiences and cognitive states. The existing literature evidences that cognitive state analysis makes

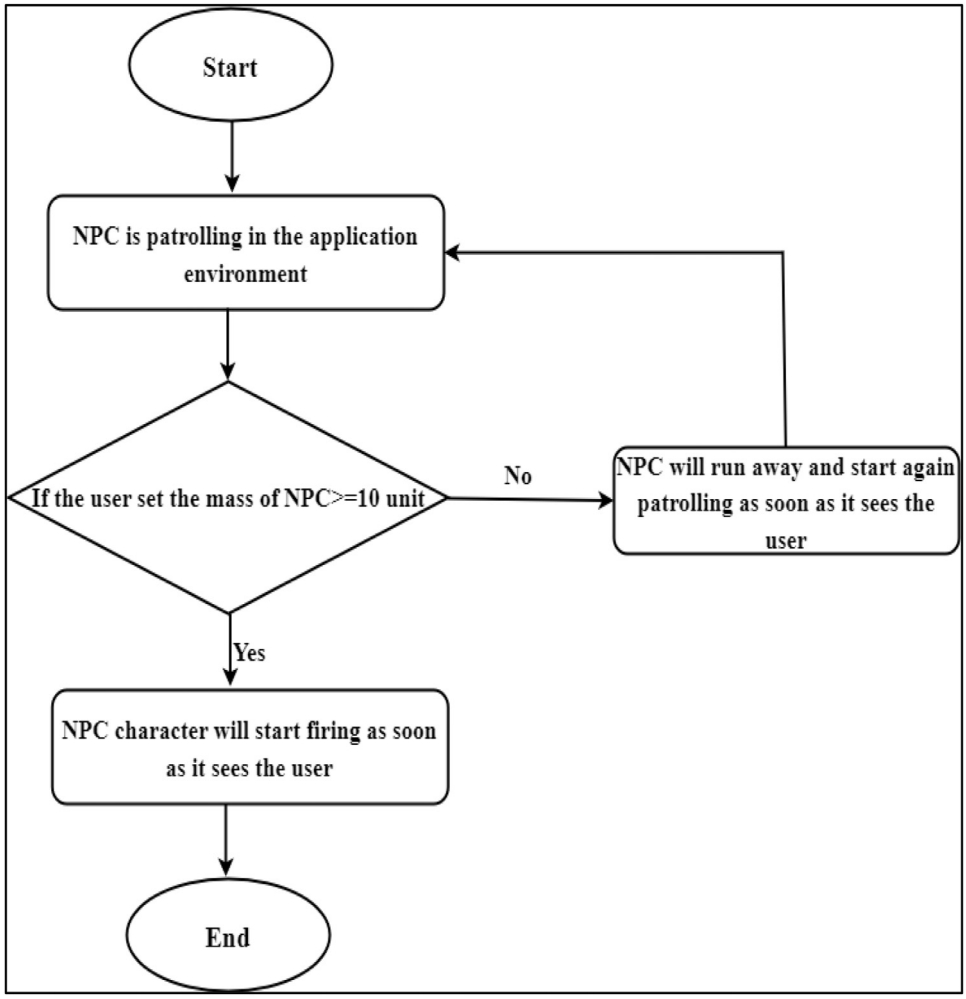

Fig. 3. The run time methodology of the non-immersive and immersive applications.

it possible to understand human behavior, improve user experience, and advance disciplines like psychology, neurology, AI, and HCI. Researchers in the present work intend to develop more context-aware and complex systems that can successfully adjust to user's emotional and cognitive needs by examining characteristics including curiosity, excitement, stress, engagement, and relaxation. To study these parameters, six users have been considered, ranging in age from 20 to 24. Data was gathered during users' interactions with the built applications using Emotiv Insight and Emotiv Pro-software. Subsequently, analysis was conducted on the acquired data. The following three scenarios are considered: Scenario 1 is when the user is not doing anything and is waiting to play the application. Scenario 2, when the user is playing the digital application on the laptop, and Scenario 3, when the user is experiencing the intelligent, interactive, and immersive application through Oculus Quest. Fig. 6(a), (b), and (c), respectively, display the images of the three scenarios.

The various cognitive parameters related to the data obtained during the experiment are illustrated in the following section:

- ***Engagement***

It expresses the degree of mental concentration and engagement with the current work. The data received from Emotiv software is in percentage format. According to Fig. 7, the users of the intelligent and interactive non-immersive application (S2) and the intelligent, interactive, and immersive application (S3) are more engaged than the users of the ideal (S1). Hence, the concentration level is higher while using the applications.

- ***Excitement***

It encapsulates both motivation and positive emotional stimulation. Users are more excited in S1 when they are waiting to experience the applications and in S3 when they are using the immersive application. In S2, when users are interacting with intelligent and interactive digital applications, the degree of excitement is at its lowest, as shown in Fig. 8.

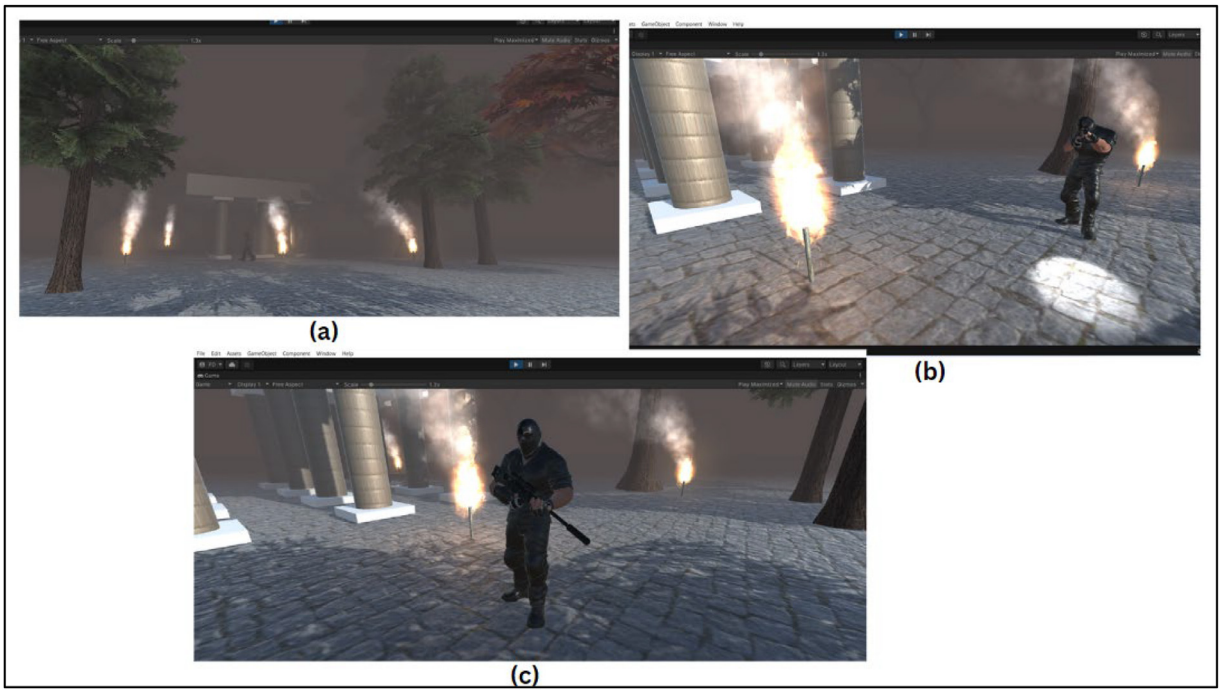

Fig. 4. The intelligent, interactive and non-immersive application.

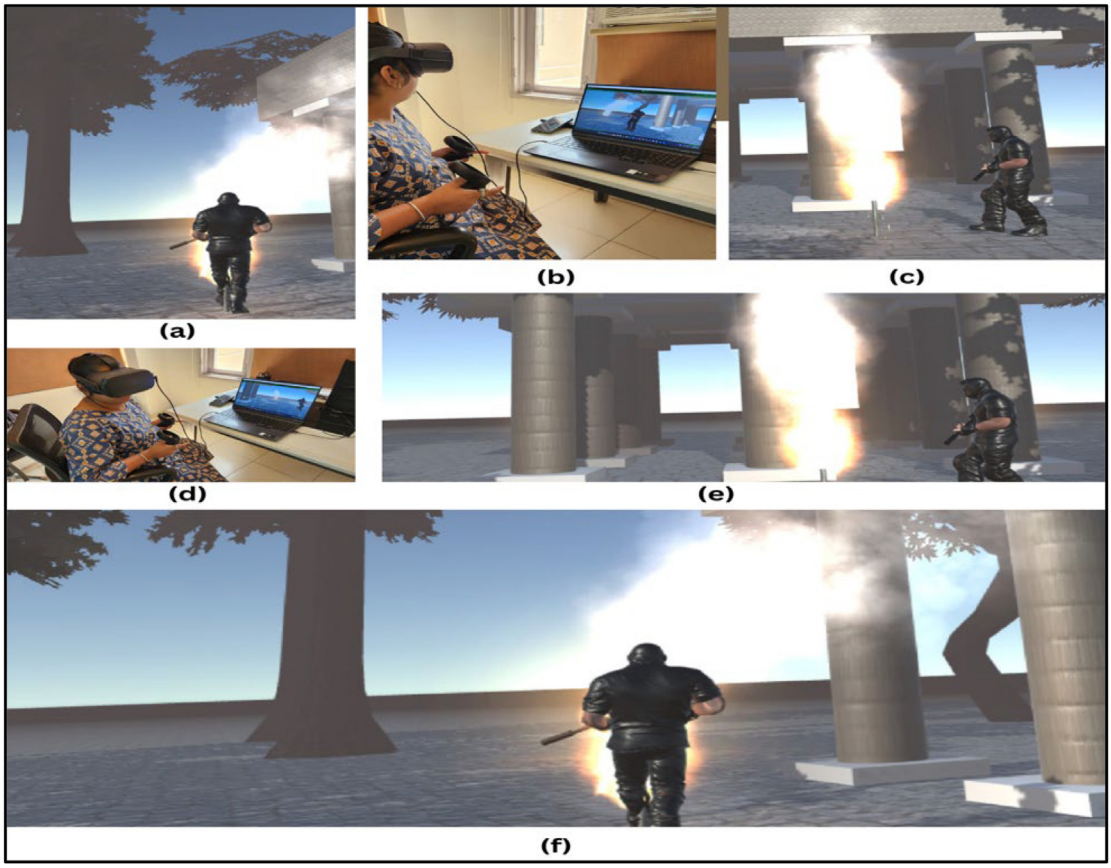

Fig. 5. The intelligent, interactive and immersive application.

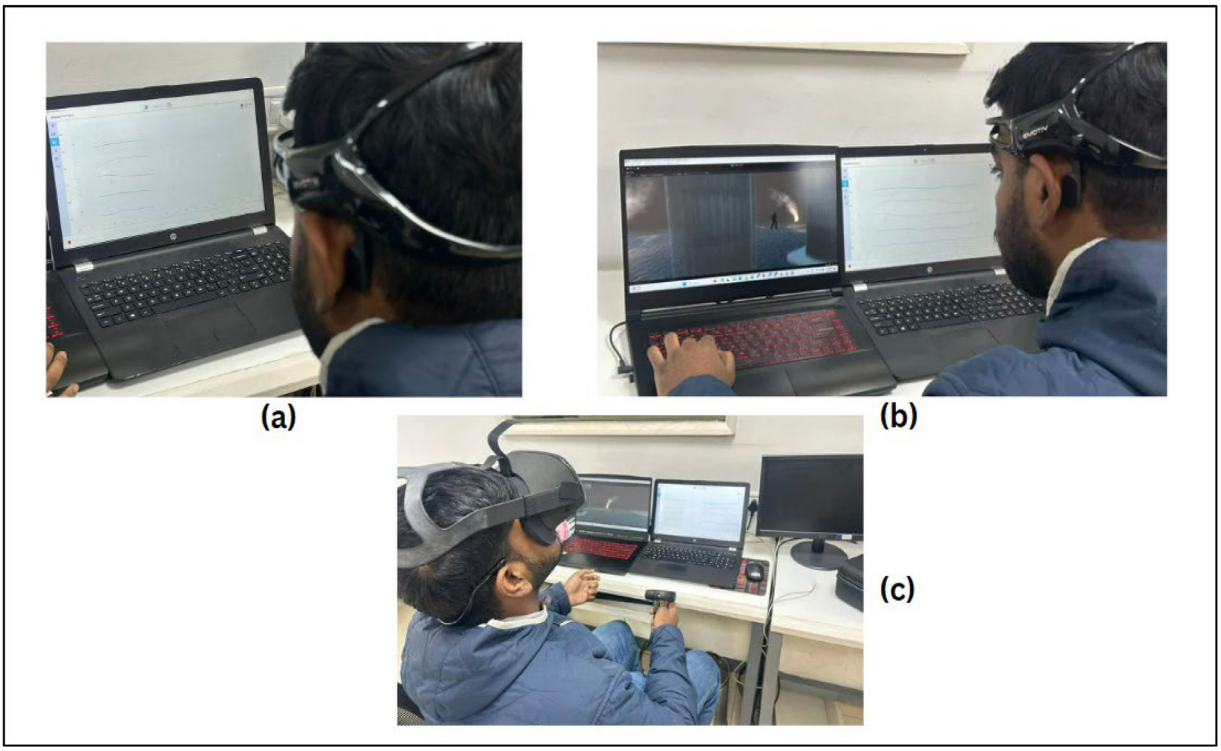

Fig. 6. The user experiencing the three scenarios.

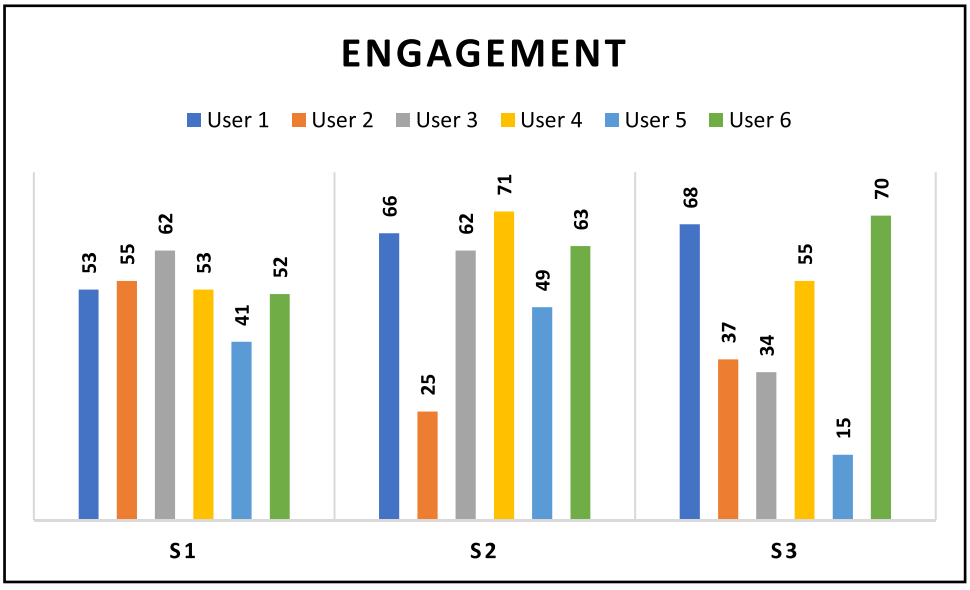

Fig. 7. The percentage of user engagement.

- ***Interest***

It measures the amount of attention focused on a certain task or stimulus. Low interest may be an indication of distraction or fragmented attention, whereas high interest suggests focused attention and strong job involvement. All users of S3 are highly interested, as depicted in Fig. 9. Therefore, it can be said that, in comparison to other scenarios, users' interest level is higher in immersive applications.

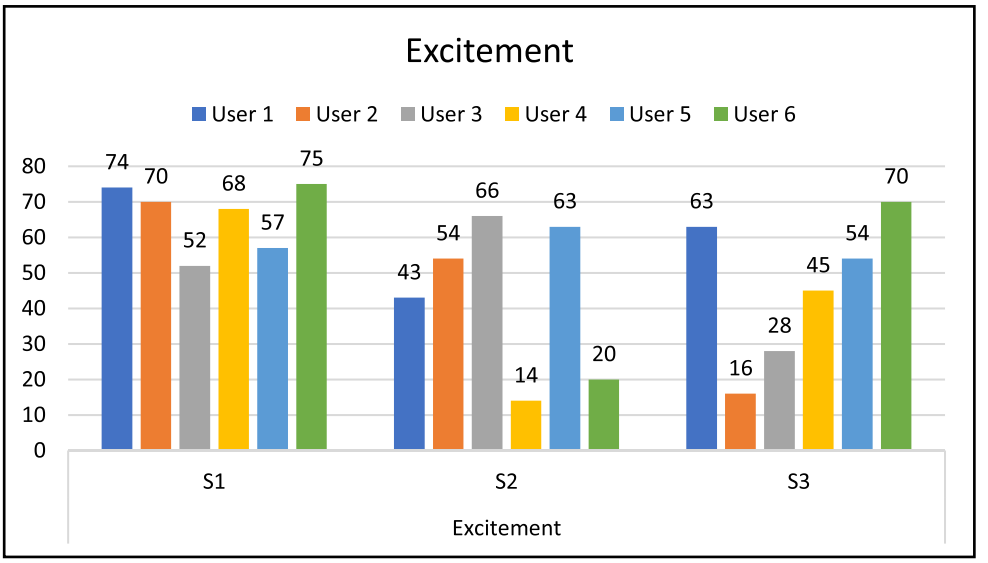

Fig. 8. The percentage of excitement of the user's.

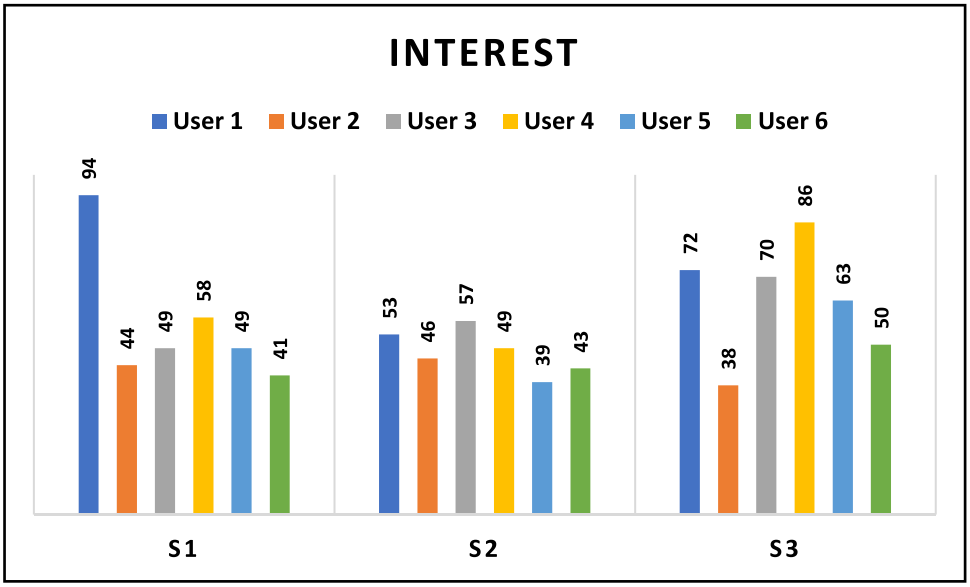

Fig. 9. The percentage of the user's interest.

- ***Stress***

It suggests that tension or mental strain is present. While moderate stress might occasionally improve alertness, high stress can have a negative impact on performance and focus. Emotiv's data indicates that users in the immersive situation (S3) are more likely to be stressed out, followed by those in the S2 and ideal scenario (S1), as shown in Fig. 10.

- ***Relaxation***

It expresses how much user id relaxed while experiencing the applications. High levels of relaxation suggest a calm and relaxed mind, while low levels may indicate an active or disturbed state. Users in an ideal condition (S1) are quite relaxed, whereas users of an immersive application (S3) are less relaxed, as seen in Fig. 11.

Discussion

Researchers have shown a significant interest in studying the affects of VR applications on many psychological parameters, such as psychological well-being, emotional responses, and cognitive performance, as evidenced by the available literature [33–35]. Present

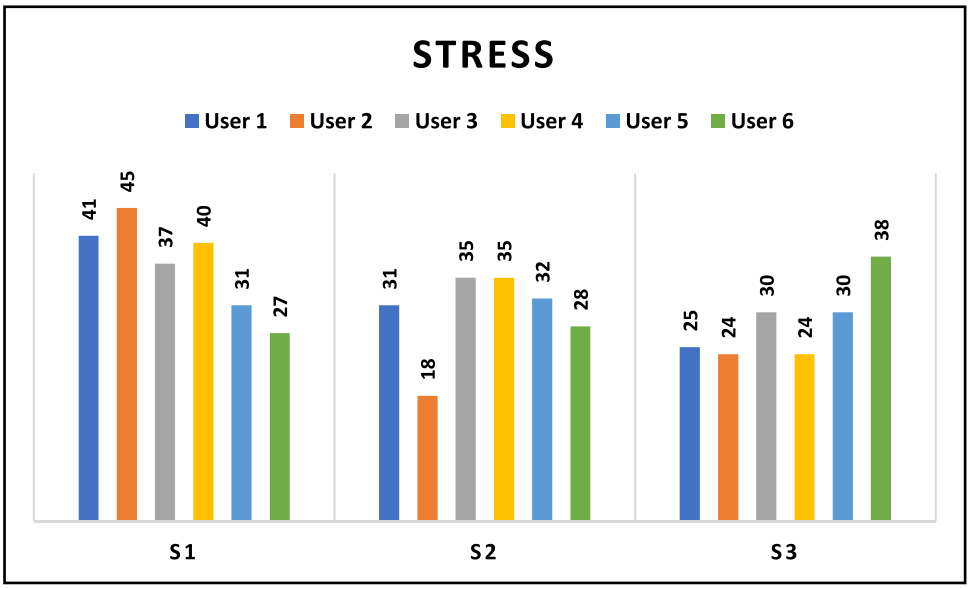

Fig. 10. The user's degree of stress.

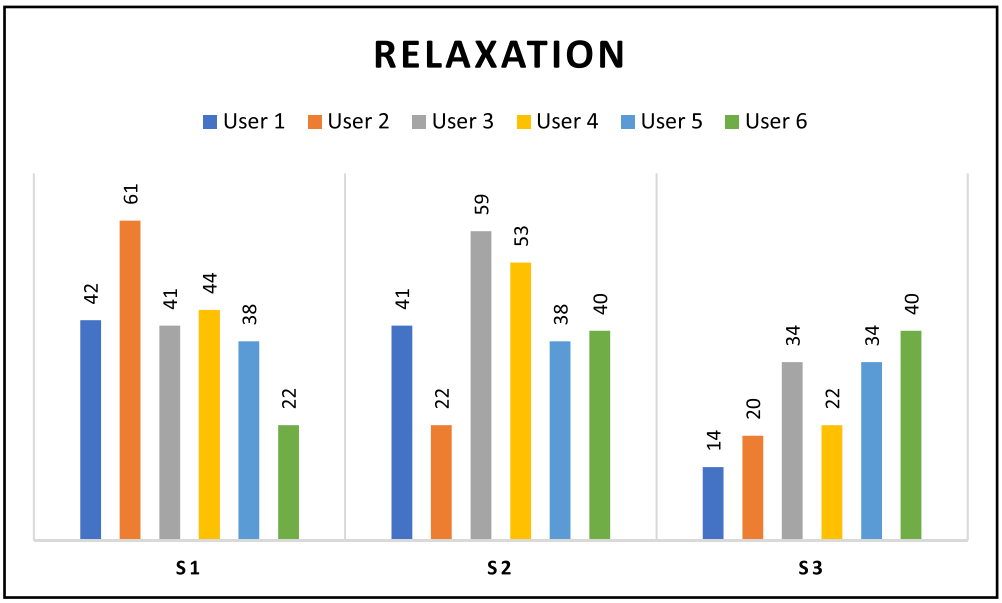

Fig. 11. The relaxation level of the user's.

research work utilized Emotiv technology in three different settings to evaluate user's psychological parameters. Scenario 1 (S1) consist of user's who are in an ideal condition, waiting to explore both non-immersive and immersive applications. Scenario 2 (S2) records interactions with the non-immersive application, whereas Scenario 3 (S3) entails immersive application utilizing Oculus Quest.

Comparative analysis between S1 and S3 reveals that only two users felt more engaged in the immersive environment compared to the ideal state, whereas three users reported higher engagement when comparing S2 to S3. This suggests increased engagement in the immersive environment, where users are detached from reality.

Furthermore, users in S1 demonstrated higher levels of excitement, maybe because they are eager to experience both non-immersive and immersive applications. Also, most of the user's (five out of six) expressed greater interest in S3 than in S1, indicating a desire for immersive experiences.

Remarkably, the study revealed that individuals in S3 had decreased stress levels in comparison to those in S1 and S2, suggesting a decrease in stress during immersive interactions. In contrast, participants in S1 and S2 indicated higher degrees of relaxation compared to those in S3, implying that immersive experiences may result in reduced relaxation levels due to fatigue, eye strain or motion sickness.

These findings demonstrate the intricate relationship between VR applications and user psychometric responses, underlining the potential advantages and difficulties involved while experiencing immersive technologies.

Conclusion

"Artificial" refers to man-made, and "Intelligence" refers to thinking power. So, AI is essentially creating thinking abilities in machines. It is a field in computer science that aims to create intelligent machines that can behave and think like humans. This includes decision-making, learning, and problem-solving. VR is yet another rapidly developing technology. Users experience a virtual environment that makes them feel as though they are in the actual world, despite the fact that they are wearing a headset. In the digital age, researchers are integrating AI with this technology to create VR experiences that are even more realistic and participatory. This study examines the psychometric characteristics of users interacting with non-immersive and immersive applications designed using the Unity 3D game engine. The applications utilize an A* pathfinding algorithm to improve their cognitive capabilities and responsiveness. With the use of Oculus Quest (a device for experiencing VR technology), the intelligent application is converted into an interactive, and immersive application. The Emotiv Insight device is further used to study cognitive factors like engagement and enthusiasm and analyze user responses when users interact with both immersive VR application and non-immersive version. The research aims to ascertain the impact of immersion on user's. The analysis depicts that greater immersion results in a more robust sense of presence, which in turn inspires user's and promotes more intense emotional involvement. This emphasizes the significance of presence and immersion in virtual worlds, implying that they may have a major influence on motivation, emotional connection, and the efficacy of the virtual worlds in various fields, including education and entertainment. For this study, six users with ages ranging from 20 to 24 are considered. It has been observed from the data that users who experience immersive applications are more interested, engaged, at ease, and less stressed. Users who are in a perfect state and are just waiting to use the applications, on the other hand, are less engaged and interested and are instead more stressed, excited, and relaxed. Immersive applications, therefore, increase engagement while reducing stress. In future studies, more number of users may be analyzed including toddlers, teen agers as well as senior citizens. Other parameters such as mental workload, decision making, fatigue can also be evaluated and analyzed. Furthermore, more enhanced equipment's like the 14-channel Emotiv can be utilized to produce more accurate, precise and reliable outcomes.

Limitations

One drawback of the A* pathfinding algorithm is its dependence on heuristics, which can sometimes provide inaccurate estimates of the cost to reach the goal. When the heuristic function used is not admissible or consistent, A* might struggle to find the optimal path, resulting in less-than-ideal or inefficient routes. In addition, the A* algorithm necessitates a significant amount of memory to manage and modify the open and closed lists, especially in extensive or intricate environments. This could affect its ability to scale effectively. In addition, A* can ensure optimal results in specific situations, like when using consistent heuristics and searching within a limited space. However, it might face difficulties in dynamic or changing environments, where the best path may require frequent recalculations. Despite its limitations, A* is still a powerful and extensively utilized algorithm for pathfinding in a range of applications. Researchers are actively investigating ways to expand and enhance A* to overcome its limitations and make it applicable to a wider range of situations.

Ethics statements

The study was conducted in accordance with the Research Ethics Committee

Data availability and access

The dataset was created by the authors themselves, and data will be made available upon request to the corresponding author.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Priyanka Datta: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition. **Amanpreet Kaur:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Resources, Supervision. **Najla Sassi:** Conceptualization, Writing – review & editing. **Yonis Gulzar:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Resources, Supervision, Funding acquisition. **Wassim Jaziri:** Conceptualization, Writing – review & editing.

Data availability

Data will be made available on request.

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