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Enhancing User Satisfaction in Virtual Reality: Insights from Interaction Methods

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Abstract. As medical education evolves, traditional training methods face challenges, particularly in Romanian faculties. This research addresses these issues by developing an innovative Virtual Reality (VR) application to enhance medical training across universities. The VR platform offers a risk-free environment for students to interact with medical objects and procedures, providing detailed performance feedback. The study focused on various interaction methods, including hand tracking and VR controllers, involving 39 participants from diverse fields and age groups. Through surveys, usability tests, and interviews, participants assessed multiple aspects of user interactions, comfort, and challenges like motion sickness and physical strain. Feedback on the effectiveness of these interaction methods for biomedical applications was collected, highlighting VR's potential to deliver a personalized and learning experience.

Keywords: Virtual Reality, Medical training, Hand tracking, Bioengineering, Infusion pump, Augmented reality, Educational technology.

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1. Introduction

As a response to the evolving needs of modern education in the medical field and given the shortcomings present in the context of education in Romania, this research addresses a specific request from the Faculty Medical Bioengineering, "Grigore T. Popa" University of Medicine and Pharmacy of Iași. This study analyzes the creation of an innovative Virtual Reality (VR) application personalized to the given request, which has as a priority the augmentation of medical training for students.

The platform offers students the possibility to interact with medical objects in a risk-free environment and based on their performance, they can receive feedback in percentages of correctness based on the level of understanding of the theoretical concepts, and based on the accuracy of the tasks. The system also monitors and evaluates the proficiency and monitors the learning progress.

This project aims to bring closer traditional medical training and the capabilities of virtual reality. The VR platform provides students with an immersive learning experience, allowing them to interact with medical instruments and objects, such as infusion pumps, used in hospitals, healthcare at home, and clinics for dosing with high-precision medication, fluids, and other substances, in a simulated environment (Hong et al., 2021; Kim et al., 2019).

This research is inherently empirical, focusing on understanding user behaviors and interactions within the context of VR-based medical training. User-centered design, which forms the core of this study, involves a comprehensive analysis of the users—their behaviors, contexts, cognitive and perceptual capabilities, and interactions with technology. By systematically observing and analyzing data, this research aims to provide new insights into how medical students interact with VR applications, revealing aspects of user behavior and its relationship with the technology, as it has become a widely used method of education (Tene et al., 2024).

To achieve these insights, the study employs an empirical methodology that includes surveys, usability tests, and interviews. Surveys will gather quantitative data on user satisfaction and the perceived effectiveness of the VR platform. Usability tests will provide qualitative insights into the ease of use and interaction challenges faced by users. Interviews will offer a deeper contextual understanding of user experiences and feedback on the system's impact on learning. The rigorous application of these methods ensures that findings are based on systematically observed data, addressing essential questions about the effectiveness of VR in medical training.

1.1. Objectives

The primary objectives of this research are:

Developing a comprehensive VR platform tailored for medical training, providing an immersive and interactive environment for students to engage with medical instruments and procedures.

Introducing an advanced grading system within the VR platform that evaluates students' performance based on task accuracy, technique finesse, and efficiency, offering a more detailed assessment than traditional methods, developed in .NET and having a Domain-Driven Design pattern (Khonov, 2021).

Implementing a progress-tracking component to monitor and analyze students' learning progress over time, enabling educators to personalize instruction and enhance learning outcomes.

Addressing potential user comfort and safety issues, including motion sickness and physical strain, and provide options for users to choose their preferred interaction method to improve the learning experience (Tian et al., 2022).

Addressing issues related to user comfort and safety, including motion sickness, physical strain, and electromagnetic radiation exposure.

Providing options for users to choose their preferred interaction method (controllers or hand tracking) to enhance the learning experience and user comfort.

1.2. Limitations

Some of the limitations present in both the developing process and the final state are the following:

Users may experience motion sickness, dizziness, or physical discomfort while interacting with the VR platform, which could affect their experience and the effectiveness of the training.

Current limitations of VR technology impact the quality and realism of simulations, potentially influencing user satisfaction and learning outcomes; however, it creates a more engaging and immersive environment, which can enhance user interest and motivation (Iftene & Trandabat, 2018).

The findings are limited by the size and diversity of the sample population. Out of the total participants, only three foreign exchange students tried the application, which may not fully represent all potential users.

Variability in how quickly users adapt to VR technology could affect their comfort levels and engagement with the training platform, an aspect that will be covered in the sample data, as individuals from all age groups are represented.

Although minimized, the potential long-term effects of exposure to electromagnetic radiation from VR equipment are not fully addressed.

2. Literature review

2.1. Existing research

In (Macariu et al., 2020), the authors discuss the use of augmented reality in teaching chemistry through their application. Similarly, in (Chitaniuc & Iftene, 2020) the authors explore the potential of augmented reality in geography education with their application GeoAR (Chitaniuc & Iftene, 2018). These applications demonstrate how immersive technologies can make abstract concepts more tangible and understandable. In computer science education, we can see how users can use a game that integrates interaction through both keyboard and mouse and with cardboard drawings, with interactive gameplay (Paduraru & Iftene, 2017). In (Simion et al, 2021), it is presented as an augmented reality piano learning tool, showcasing how AR can facilitate music education by providing real-time feedback and interactive learning experiences. Additionally, in (Chitaniuc et al., 2018) the authors show how they developed FoodAR - An Augmented Reality Application used in Gastronomy, highlighting the versatility of AR in practical fields such as culinary arts. In (Pinzaru & Iftene, 2016), the authors present Sphero - Multiplayer Augmented Game (SMAUG), which demonstrates the use of AR in interactive, multiplayer gaming environments.

In the context of interaction, some recent studies have contributed important insights into the effectiveness and user preference of different VR interaction methods. These studies explore how various input mechanisms - such as controllers, hand tracking, and bio-sensors affect user experience, precision, and engagement.

In (Rantamaa et al., 2023), the authors evaluated various VR interaction methods, including controllers with styluses and hand tracking. They found that the controller and stylus combination was more accurate and easier to use compared to hand tracking, which struggled with precision and feedback. This study underscores the role of effective feedback in enhancing VR interactions. In (Kim et al, 2023), the authors examined the integration of bio-sensors like eye-tracking and EEG into VR locomotion methods. They found that eye-tracking excelled in location targeting, while hand-tracking was more effective for teleportation. Their research highlights the benefits of combining different tracking technologies to improve VR navigation. In (Juan et al., 2023), the authors compared hand-based and controller-based interactions for upper limb rehabilitation in VR. They discovered that hand interactions were preferred for their natural feel and were especially beneficial for users with motor impairments. This preference indicates that natural hand gestures can enhance engagement and motivation in therapeutic VR settings.

2.2. Gaps

Despite the valuable insights provided by the aforementioned studies, there is a notable gap in research specifically addressing VR applications tailored for bioengineering students. While the studies offer important findings for related domains - such as medical training, rehabilitation, and general VR interaction - they do not focus on the unique needs and contexts of bioengineering education. The results from these studies also present somewhat contradictory outcomes, reflecting the diverse requirements and applications of VR technology in various contexts. Therefore, further research is needed to explore and optimize VR interactions specifically for bioengineering students, addressing the challenges and opportunities in this educational domain.

3. Methodology

3.1. Design

The primary focus of this study is on understanding user experiences, preferences, and interactions with the VR platform. Therefore, a qualitative approach is employed, which emphasizes gathering detailed, descriptive data about how users engage with the system. This approach is ideal for exploring user comfort, satisfaction, and the nuances of their interactions with the VR application. Given that less than 40 participants were involved, qualitative methods like interviews and open-ended survey questions are particularly suitable for gaining insights into their experiences.

3.2. Participants

The participants in this study were a carefully selected group from the Faculty of Medical Bioengineering, Faculty of Computer Science and other. The sample consisted of 39 individuals, including medical students, faculty members, and technical experts, all of whom were directly relevant to the VR platform's use. The participants represented a diverse demographic, including various age groups and levels of experience with VR technologies and. This diversity included individuals with varying degrees of familiarity with biomedical education. The inclusion of three foreign exchange students added an international perspective, enriching the study with insights from users with different cultural and educational backgrounds.

3.3. Data collection

In-depth interviews were carried out with participants to gather detailed feedback on their experiences with the VR platform. Additionally, open-ended survey questions allowed users to provide descriptive responses about their comfort, usability, and satisfaction with the system. Structured surveys were used to collect numerical data on user satisfaction and performance metrics. This included 5-point Likert scale questions to quantify aspects of user experience and system effectiveness (Ankur et al., 2015).

3.4. Data analysis

Thematic analysis was used to identify recurring themes and patterns in the interview transcripts and open-ended survey responses. This process involved coding the data to categorize and interpret user feedback on various aspects of the VR platform, such as usability, comfort, and interaction preferences, resulting in qualitative aspects.

To ensure the quantitative analysis, statistical analysis was applied to the structured survey data to identify trends and patterns in user satisfaction and performance. This included calculating descriptive statistics, such as means, to assess user satisfaction and identify areas for improvement, which were easily accessible from the Google Form responses graphs.

3.5. Results

3.5.1. Findings

The survey results from the participants provide several important aspects of the platform. These insights reveal key strengths and areas for improvement, offering a comprehensive view of user experiences and preferences.

Figure 1. The hand (wrist) menu interface of the VR application, showcases its intuitive design and interactive elements.

Most participants found the VR application's interface highly intuitive, with 85% rating it at the maximum score of 5. This high rating reflects a user-friendly design, important for effective engagement with the application.

The hand menu, shown in Figure 1, demonstrates the interface’s layout and functionality, as well as a form of interaction. The positive feedback suggests that the interface design successfully supports user interaction and task completion. Additionally, the high satisfaction with the interface indicates that users felt comfortable navigating the VR environment, which likely contributed to their overall positive experience with the application.

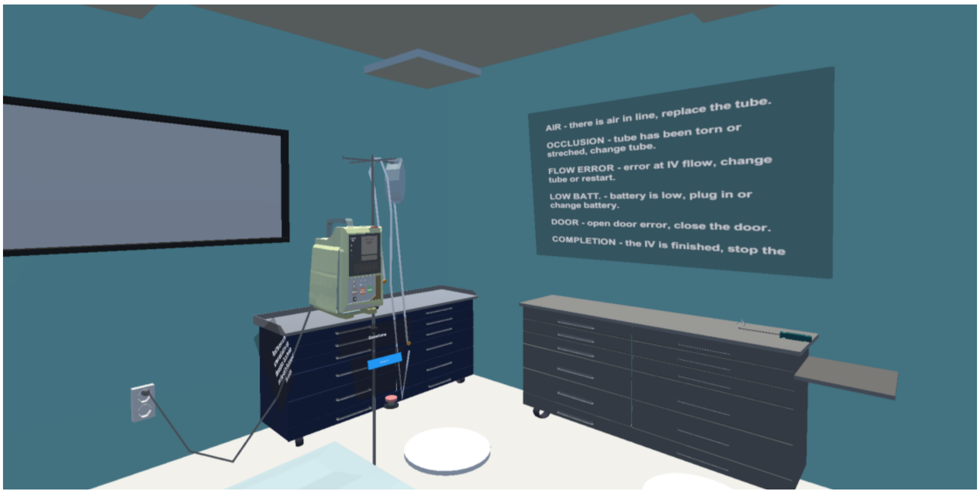

Figure 2. The functionality test scene of the VR application, demonstrating user interaction with the virtual environment.

The VR application was also praised for its effectiveness in teaching the operation of an infusion pump. An impressive 90% of users rated this aspect as highly effective, indicating that the VR simulation is a good educational tool. Figure 2 illustrates a scene where the users must learn the error codes and the series of steps which must be taken in order to operate and react correctly to the error codes showcased on the infusion pump's screen. After the alarm is stopped by doing the right actions, such as closing the pump, or adjusting the flow, the drop down menu under the pump provides a multiple answer question about the process.

Participants overwhelmingly appreciated the realism of the simulation, with 88% rating it at the highest level. This indicates that the VR environment successfully mimics real-life operations, making the learning experience both engaging and authentic. However, feedback also highlighted that while most users felt the VR application covered essential aspects of infusion pump operation, a few suggested that some areas could be further detailed.

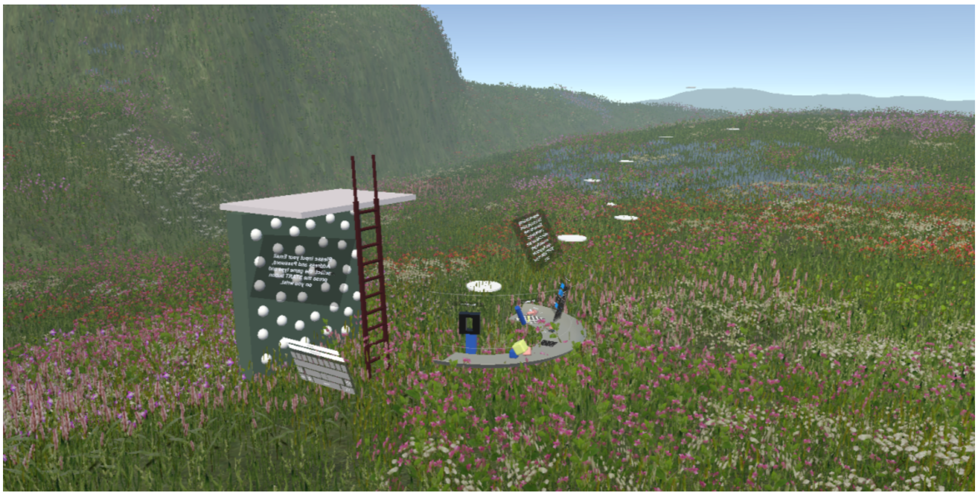

Figure 3. The VR lobby where users select their interaction method.

When it came to interaction methods, a notable preference emerged: 68% of users favored using XR hands over controllers. This preference suggests that the ability to use natural hand movements rather than traditional controllers enhances the immersive experience. Figure 3 shows the VR lobby where users select their interaction method, emphasizing the flexibility offered by the application.

On the grading system's side, users found the application's interface to be highly effective for tracking student progress and managing educational data. With 87% rating its usefulness as 5, the grading system plays a very important role in the educational framework. The application's capability to provide real-time updates and detailed reports was particularly appreciated.

Despite these positive findings, some users reported mild discomfort during VR use, such as headaches or dizziness.

3.5.2. Analysis

The results suggest that both the VR application and grading system effectively meet their respective goals. The VR application is particularly well-received for its intuitive design and realistic simulation, which are key factors for immersive learning. The preference for XR hands-on controllers' points to the value of providing flexible interaction options, allowing users to engage more naturally with the VR environment.

Table 1 - Mean values and standard deviations of user ratings for the VR and web applications (ratings are out of a maximum of 5, from 39 users).

Inquiry	Mean (Out of 5)	St. Dev.
Intuitiveness of VR interface	4.8	0.4
Effectiveness in teaching infusion pump	4.9	0.3
Realism of VR simulation	4.8	0.5
VR application covers key aspects	4.9	0.3
Usefulness in responding to alarms	5.0	0.0
Ease of assembling infusion pump in VR	4.9	0.3
Advantage of using controllers	5.0	0.0
Ease of using web application interface	4.9	0.3
Usefulness of web application for tracking progress	4.8	0.5
Real-time viewing of status	5.0	0.0
Integration of web application into learning	4.9	0.3
Comfort while using VR	4.8	0.4
Confidence in operating infusion pump post-usage	4.7	0.6
Overall satisfaction with applications	4.9	0.3
Percentage Satisfaction	98%	

The grading system's positive reception underscores its importance in supporting educators with effective tracking and management tools. The user ratings reveal high scores across various metrics, with an overall satisfaction rating of 4.9 out of 5, 98% satisfaction percentage respectively. However, the reported discomfort experienced by some users suggests areas for improvement in user comfort, which is essential for ensuring a positive and sustained experience with the VR application.

Table 2 - Summary of affirmative responses regarding the VR application's impact on health and usability (ratings from 39 users).

Inquiry	Affirmative Responses Percentage
The VR application enhances learning	90%
The interface is user-friendly	85%
Preference for Controllers	41.2%
Preference for XR Hands	58.8%
Experience of discomfort	10%

Table 2 reveals important insights about user perceptions of the VR application.In terms of interaction preferences, 58.8% prefer XR hands over traditional controllers (41.2%). However, 10% of users reported discomfort, suggesting the need for improvements in user comfort, tested in the context of prolonged use, as eye strain, dizziness and heat discomfort.

3.5.3. Age groups

Participants of various ages rated the VR and grading system positively.

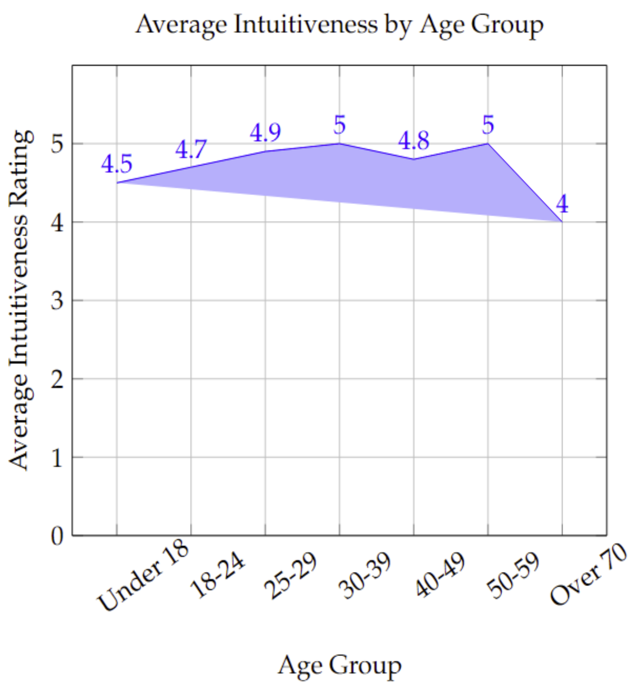

Figure 4. Average intuitiveness ratings of the VR application by age group.

Notably, the 18-24 age group gave higher ratings across all metrics, including interface intuition, teaching effectiveness, and simulation realism. This group also reported higher comfort levels compared to older age groups. Conversely, the 50-59 age group showed slightly lower scores across all categories, particularly in comfort, suggesting that older users might be more sensitive to VR-related discomfort.

3.5.4. Gender

Differences in responses were subtle yet noteworthy. Participants who identified as women rated the interface intuition, teaching effectiveness, and simulation realism slightly higher than men. Non-binary respondents, though fewer in number, had the highest ratings across all categories. However, due to the small sample size of non-binary respondents, these results should be considered preliminary.

3.5.5. Role and experience level

The analysis by role and experience level highlighted interesting trends.

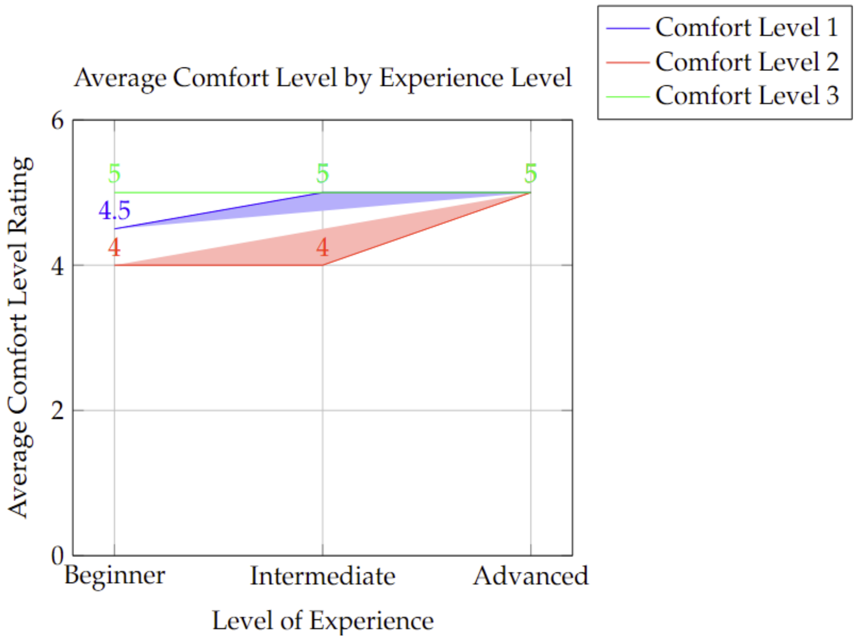

Figure 5. Average comfort level by experience in VR

Computer Science students generally rated the VR application slightly higher in terms of interface intuition and teaching effectiveness compared to other groups. Bioengineering students and casual users also provided positive feedback but with somewhat lower ratings. Notably, professors rated the application highly across all metrics.

The data indicates that beginners reported an average comfort level of 4.5, showing that while the application is accessible, some users still face challenges. In contrast, intermediate and advanced users both rated their comfort at 5.0, suggesting that increased familiarity enhances engagement and confidence in using the technology.

3.6. Discussion

3.6.1. Interpretation of findings

The high ratings for the VR application's interface intuitiveness and effectiveness in teaching indicate that it meets the educational objectives set for it. The high realism ratings further validate its success in creating an engaging and realistic learning environment. The preference for XR hands-over controllers highlights how important it is to offer users flexible interaction options. This choice allows users to select the interaction method that best suits their personal preferences and enhances their experience.

The positive feedback on the grading system's ability to track and manage student progress confirms its important role in the educational process. However, the discomfort reported by some users, such as mild dizziness or headaches, indicates that refinements are needed to improve user comfort and minimize any negative effects associated with VR use.

3.6.2. Implications for design

These findings have several implications for future design improvements. The preference for XR hands-over controllers indicates that offering users the choice between different interaction methods is important. This flexibility should be maintained and potentially expanded to include more customization, enhancing user satisfaction and immersion. Allowing users to select an interaction method that feels most natural to them will improve their experience and engagement with the application.

The feedback highlighting the need for more detailed coverage of certain aspects of infusion pump operation suggests that the VR application should continuously evolve to cover all essential aspects comprehensively. Expanding and refining the content will ensure that the VR application remains an important educational tool and meets diverse learning needs.

In terms of user comfort, ongoing adjustments to the VR experience are necessary to minimize discomfort and ensure a positive user experience. This could involve optimizing visual settings and refining the VR environment to reduce adverse effects.

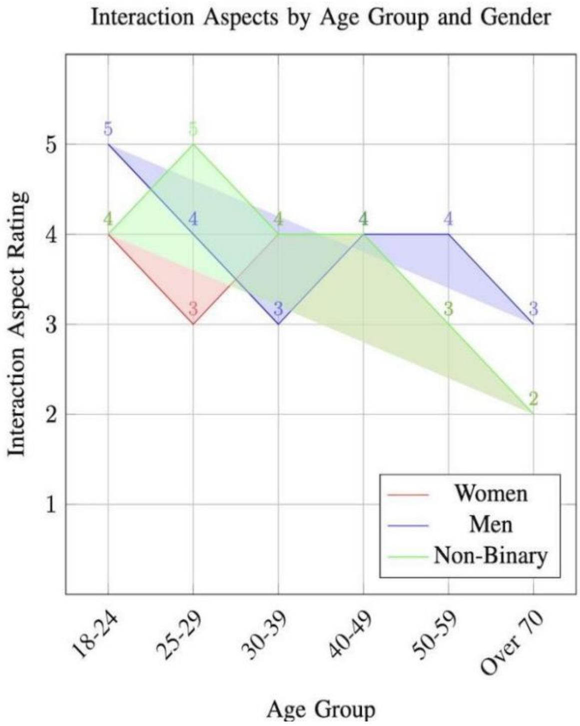

Figure 6. Interaction aspects of VR application and grading system by age group and gender.

Contextual factors such as age, gender, and VR experience level can influence user interaction and satisfaction. As an example, younger users (18-24 years) generally reported higher satisfaction and comfort levels, while some older users experienced more discomfort. Additionally, non-binary and women showed a tendency to rate the application more favorably, but non-binary users were underrepresented in the sample. Notably, some specific abnormalities, such as a preference for controllers among older users and a higher incidence of discomfort reported by women, suggest areas for targeted improvements. However, the high levels of discomfort were related to a slightly higher number of cases of mild dizziness, while participants who identified as men suggested a lot lower toleration to the high temperature released by the headset, after prolonged usage time (Rupp, 2024). Personalizing the VR experience to address these demographic-specific needs will enhance effectiveness.

4. Conclusion

The evaluation of the VR application and the grading system has demonstrated their effectiveness and utility in educational settings, particularly in teaching the operation of an infusion pump. High ratings for interface intuitiveness, realism, and educational effectiveness indicate that the applications successfully meet their primary objectives. The preference for flexible interaction methods, such as XR Hands, highlights the importance of user-centered design in enhancing user experience and engagement.

4.1. Recommandations

Several key recommendations can be made to enhance VR applications, with a focus on inclusivity, user comfort, and the importance of freedom of choice in user interfaces.

Promoting inclusivity involves acknowledging and addressing the diverse needs of users from different demographic backgrounds. It's essential to develop the VR experience to consider specific issues reported by various user groups, such as older users and women who reported higher instances of discomfort. This approach will create a more inclusive learning environment.

Enhancing interaction flexibility by continuing to offer and potentially expanding the choice between XR hands and controllers can improve user satisfaction and engagement. Providing users with the flexibility to choose their preferred interaction methods makes the application more accessible to a broader audience and creates a more inclusive environment in the context of education.

User comfort is one of the prevalent issues in the current context of VR headsets. Implementing adjustments to the VR experience to minimize discomfort, such as dizziness and headaches, will ensure a positive user experience. This can be achieved by designing the user interface and the game such that short breaks can be taken anytime, and the headset is not used for prolonged periods of time when solving the tasks in the applications.

4.2. Future work

Although the current application is complete and has shown positive results, future work will focus on exploring various UI and interaction methods to enhance its usability and scalability. Testing different interaction methods will help identify the most effective approaches for a broader group of students. By doing so, we aim to adapt the application for larger-scale use without compromising the needs of individual students from the Faculty of Medical Bioengineering.

Future iterations will prioritize maintaining a balance between meeting diverse user preferences and achieving widespread applicability. This process will involve continuous user testing and feedback collection to ensure that the application remains inclusive. By refining the interaction methods and UI design, we can create a more flexible and adaptable learning tool that benefits a wider audience while preserving personalized experiences.

Future enhancements will take into consideration the current user interface of the app, examining how the selected interaction method integrates with the UI design, beyond just the tasks performed by students. An adaptive learning algorithm will be implemented to tailor the VR experience to individual learning needs, allowing for personalized adjustments. This approach will involve studying the interaction methods in relation to both the UI and the adaptive learning requirements, ensuring that the application effectively supports diverse learning styles and user preferences.

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