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Immersive Virtual Reality to Support Blood Donation: A Pilot Study on Engagement and Anxiety Reduction

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Abstract

The shortage of blood donations remains a major public health issue, especially among younger adults whose participation has declined. This study presents the design and evaluation of an immersive virtual reality (VR) experience aimed at reducing anxiety and encouraging blood donation. Based on the Theory of Planned Behavior and a review of 166 studies, the VR prototype offered educational, calming, and interactive settings such as a theater, library, meditation room, arcade, and art gallery. Twenty-two participants aged 18–39 completed pre- and post-surveys on satisfaction, anxiety, usability, and donation intention. Results showed 82% were very or extremely satisfied, and 64% reported greater willingness to donate. The arcade and art gallery were the most popular features, while 41% experienced cybersickness, pointing to design refinements needed. These findings suggest VR can help lower barriers to blood donation and engage younger donors. Future work will refine technical performance, broaden content, and test long-term behavioral effects in larger studies.

Keywords: Virtual reality, blood donation, donor recruitment, immersive technology, anxiety reduction

1. INTRODUCTION

Blood donation remains a cornerstone of modern healthcare, providing essential support for surgeries, trauma care, cancer treatments, and chronic illnesses. Despite this critical need, blood supplies in many regions, including the United States, have faced persistent shortages. According to recent estimates, although approximately 62% of Americans are eligible to donate blood, only about 3% do so regularly (Keyser et al., 2025). This gap between eligibility and participation poses significant challenges for maintaining a stable blood supply.

The problem is especially pronounced among younger adults. From 2019 to 2021, donations among individuals aged 16–24 dropped sharply, driven in part by the COVID-19 pandemic's impact on donation events and broader shifts in attitudes and lifestyle. Common barriers identified in prior research include fear of needles, discomfort with medical environments, lack of time, and limited awareness of the need for donation (Armitage & Conner, 2001; Lemmens et al., 2009).

VR is an emerging tool to address these challenges. Prior studies show that VR can reduce anxiety and increase engagement in healthcare, from surgical preparation to phobia treatment. In the blood donation context, VR may combine education, distraction, and relaxation to make the process less intimidating. It can also create positive associations for younger donors who are comfortable with interactive media. Yet, its use for blood donation has been studied little.

This study presents the design and pilot evaluation of a VR application developed to support donor education and reduce anxiety. The intervention was informed by the Theory of Planned Behavior and prior research on donor motivations and technology-enabled engagement. The goal was to assess the feasibility, acceptability, and perceived impact of the VR experience on participants' attitudes and willingness to donate blood.

2. LITERATURE REVIEW

The persistent shortage of blood donations remains a critical public health concern in the United States and worldwide. According to Keyser et al. (2025), while approximately 62% of the U.S. population is eligible to donate blood, only about 3% donate each year, underscoring an urgent need to attract and retain new donors. Declines have been most severe among younger age cohorts: from 2019 to 2021, donations fell by 62.5% among individuals aged 16–18 and by 34.9% among those aged 19–24, partly due to the COVID-19 pandemic's impact on school-based drives and partly due to broader shifts in attitudes and habits among young adults. Additional factors, including fear of needles, lack of time, perceived inconvenience, and distrust in healthcare institutions—contribute to this trend (Keyser et al., 2025).

To address these barriers, more research has explored emerging and disruptive technologies such as mobile applications, gamified engagement, mixed reality (MR), and VR. Ghouri et al. (2023) advocate the integration of technologies such as blockchain, AI, and neural networks to improve the transparency, safety, and efficiency of donation systems.

Evidence supporting the use of VR in blood

donation contexts is robust. A pilot study published in Transfusion found that 68.4% of donors who used MR during blood collection reported a measurable reduction in pre-donation anxiety (Pandey et al., 2024). Williams et al. (2024) demonstrated that immersive VR interventions elicit positive emotions and can reassure donors, contributing to improved willingness to return. Research showed VR interventions can improve mood and significantly reduce tension and fear of needles in first-time donors (Tarrant et al., 2019). Additionally, Deighan et al. (2024) reported that while healthcare professionals recognize the promise of VR in clinical workflows, they note the importance of addressing challenges such as motion sickness and usability constraints in confined donation spaces.

The ACM Symposium on Virtual Reality Software and Technology presented further evidence of VR's motivational potential, leveraging the Proteus effect—where users' avatars progressively became more energetic and positive as they engaged with a donation simulation—to foster positive associations with the donation experience among young adults. Mäkinen et al. (2020) concluded from a systematic review that VR supports enhanced learning and engagement in healthcare training, suggesting similar potential to educate and motivate donors.

To bridge knowledge gaps and address behavioral barriers, our team's prior work (Keyser et al., 2025) synthesized 166 studies and recommended integrated interventions combining accurate education, interactive components, and opportunities for self-directed exploration. This recommendation aligns with the Theory of Planned Behavior (TPB), which identifies perceived behavioral control, subjective norms, and attitudes as the primary predictors of donation intention (Ajzen, 1991). Studies applying TPB in blood donation contexts (Armitage & Conner, 2001; Lemmens et al., 2009) have underscored the importance of providing clear information and reinforcing perceptions of control and self-efficacy.

These insights directly informed the design of our VR system. The prototype combines a suite of selectable environments: (1) a virtual theater offering high-quality informational videos on the donation process and its lifesaving impact; (2) a library where users can read articles and complete interactive quizzes to reinforce learning; (3) a meditation room with calming natural scenery and guided breathing exercises to reduce anxiety; (4) an arcade with simple, low-effort games designed to distract and occupy the donor during the procedure; and (5) an art gallery featuring curated works with optional descriptive captions. This approach aims to build confidence, alleviate fear, and strengthen positive associations with donation, especially in the critical 18–39 age group.

3. METHODOLOGY

This project followed a multi-phase, mixed-methods research design combining literature review, user-centered design, prototype development, and pilot evaluation.

Phase 1: Literature Review and Needs Assessment
We conducted a systematic literature review informed by PRISMA guidelines, examining 166 peer-reviewed studies published between 1970 and 2024 (Keyser et al., 2025). Search queries included "blood donation barriers," "emerging technology in donor recruitment," and "VR in healthcare education." Major themes were synthesized and mapped to the Theory of Planned Behavior framework to identify determinants of donation intention.

Phase 2: Prototype Design
Drawing on research showing that VR can help reduce anxiety and improve engagement, we developed the VR prototype in Unity 3D and tailored it for Oculus Quest 2 and 3 headsets. Table 1 provides an overview of the main features and the reasons behind their inclusion. The design focused on four key priorities:

Educational Relevance: Delivering clear, factual information about the donation process, its benefits, and overall safety.

Anxiety Reduction: Offering calming environments, guided breathing exercises, and options for distraction, whether passive or interactive.

User Agency: Using a simple navigation model so donors could easily choose the environment that suited them best.

Accessibility: Keeping interaction straightforward and comfortable for people who would have a needle in one arm during the experience. The one-handed control setup allowed users to explore and interact without needing both hands.

Feature	Description	Rationale
Educational Theater	Informational videos with donation process and its impact	Increase knowledge; correct misconceptions
Library w/ Trivia	Articles; interactive questions	Reinforced learning; confidence building
Meditation scenery	Calming visuals; guided breathing	Reduce anxiety & stress
Arcade Games	Simple engaging activities	Distraction & fun
Art Gallery	Curated artworks with captions	Additional calming content

Table 1: VR Prototype Design Overview

Phase 3: Iterative Development and Pilot Testing

During the pilot testing sessions, participants were invited to a controlled lab environment where they received an orientation on the VR equipment and study purpose. Each participant completed the pre-survey before being fitted with the VR headset. They were guided through calibration and shown how to navigate the scene selection menu using their unoccupied hand. Participants then explored each of the five VR scenarios at their own pace, spending approximately 20–30 minutes in total. Research staff observed interactions unobtrusively, recording notes on usability issues, observed discomfort, and participant questions. After completing the experience, participants immediately completed the post-survey and were encouraged to elaborate on their ratings and suggestions in open-ended responses. Data were collected anonymously and linked using participant IDs for paired pre/post analysis.

The prototype underwent iterative refinement with feedback from stakeholders, including healthcare professionals and prospective donors aged 18–39. Usability issues—such as headset fit, navigation clarity, and cybersickness—were systematically documented and addressed.

Phase 4: Evaluation

Participants completed a pre-survey capturing demographic data (age, gender, prior donation history, prior VR experience) and attitudes about blood donation and VR. The post-survey included ratings of overall satisfaction, experiences of cybersickness, perceived anxiety reduction, favorite scenarios, interaction effectiveness, helpfulness of hints, suggestions for improvement, and willingness to recommend the program. Participants also reported whether the VR experience increased their inclination to donate and provided open-ended feedback describing their feelings during specific activities. Quantitative items were summarized with descriptive statistics, while qualitative responses were thematically coded to identify patterns in perceived effectiveness, usability, and emotional impact.

Ethics

This study protocol was reviewed and approved by the relevant institutional ethics board. All participants provided informed consent.

5. Results

Participants were recruited through campus flyers, classroom announcements, and word-of-mouth among college students. The final sample consisted of 22 participants aged 18 to 26. The demographics information is shown in Table 2. Almost half (46%) were between 18 and 20 years old, with another 46% between 21 and 23, and one participant aged 26. The majority identified as female (59%), with 36% identifying as male and 5% as another gender.

Variable	Category	N	%
Gender	Female	13	59%
	Male	8	36%
	Other	1	5%
Age Group	18–20	10	46%
	21–23	10	46%
	24–26	1	5%
Education Level	College	21	95%
	Graduate School	1	5%
Prior Donation	Yes	7	32%
	No	15	68%
Prior VR Experience	Yes	11	50%
	No	11	50%

Table 2: Demographics information

Education levels were diverse, with 32% of participants in their final year of college, 41% enrolled in college without senior standing, and smaller groups representing juniors, freshmen, and graduate students. Approximately one-third of participants (32%) reported having previous experience in blood donation, while two-thirds never donated blood. Prior VR experience was evenly distributed, with 50% indicating they had used VR before and 50% reporting no prior experience. This demographic diversity provided a relevant perspective on the usability and

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perceived impact of the VR intervention targeting young adults.

All participants completed the pre- and post-surveys following the VR experience. Overall satisfaction with the program was high, with 82% (18 participants) rating their experience as "Very Satisfied" or "Extremely Satisfied," and 18% (4 participants) indicating a neutral response. No participants reported dissatisfaction. The most frequently cited positive aspects included the variety of interactive environments and the informative content, particularly in the arcade and art gallery scenarios.

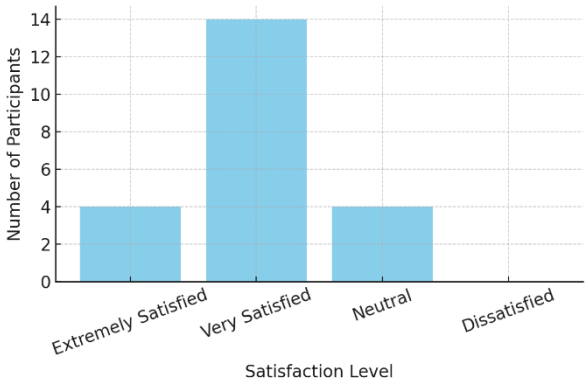

Figure 1: Overall satisfaction with VR prototype

Cybersickness was reported by 9 participants (41%), with symptoms ranging from mild dizziness and nausea to eye discomfort. Notably, several participants who experienced cybersickness still expressed overall satisfaction with the program.

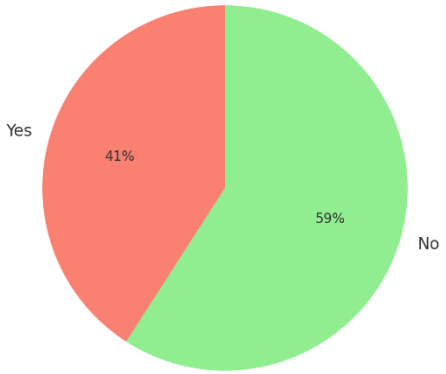

Figure 2: Participants reporting cybersickness

Half of the participants (11) indicated that the VR activities helped alleviate their concerns about blood donation. Among the factors contributing to reduced anxiety were the immersive distractions (e.g., arcade games, art gallery) and the clear, structured information provided in the library and theater environments. For some participants, the calming visuals and guided breathing in the meditation scene also played a role in reducing stress.

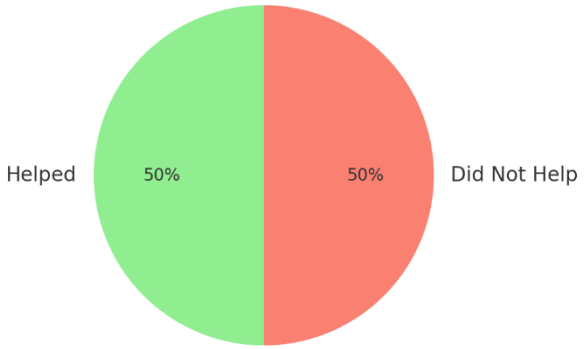

Figure 3: Concern alleviation.

The arcade and art gallery were the most popular activities, selected as favorites by 16 and 13 participants respectively. The library was endorsed by 9 participants for its educational value, though it was also among the most commonly cited least favorite experiences, along with the meditation room, due to overstimulation or confusion about purpose. Several participants noted that more instructions and clearer navigation cues would improve usability.

Regarding interaction effectiveness, 11 participants reported being able to interact effectively with the VR environment, while 10 indicated they were somewhat effective, suggesting moderate learning curves and opportunities for refinement. Hints provided within the program were rated as helpful or very helpful by most respondents (86%).

Importantly, 64% of participants (14) stated that they were more inclined to donate blood after completing the VR experience. Reported reasons included increased understanding of the process, reduced anxiety, and the appeal of engaging distractions during donation. Five participants indicated they were less inclined, primarily due to persistent needle anxiety or discomfort with VR itself.

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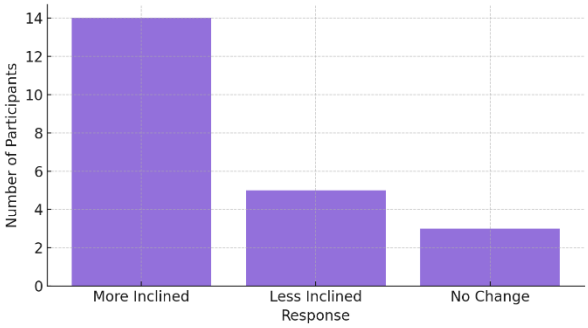

Figure 4: Change in willingness to donate blood

On a scale from 1 to 10, the likelihood of recommending the VR program to others averaged approximately 8.3, with scores ranging from 3 to 10. The most frequent ratings were 8 and 10, reflecting positive overall perceptions.

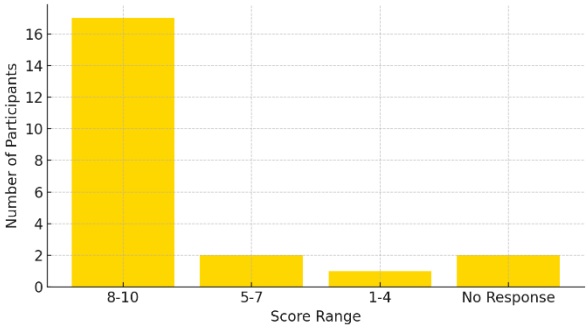

Figure 5: Recommendation likelihood (1-10 scale).

6. DISCUSSIONS

Overall, the findings indicate that VR interventions hold considerable promise for enhancing donor education, reducing anxiety, and increasing willingness to donate.

Participants' satisfaction ratings were largely positive, with 82% reporting being "Very Satisfied" or "Extremely Satisfied." This aligns with prior research showing that immersive technologies can elicit positive emotional responses and improve perceptions of medical procedures (Williams et al., 2024; Pandey et al., 2024). Notably, 64% of participants reported that the VR experience increased their inclination to donate blood, suggesting the approach is effective in addressing attitudinal barriers.

The most frequently endorsed features were the arcade and art gallery, underscoring the value of interactive and visually engaging environments for distraction. This supports the design rationale that combining educational components with appealing, low-pressure activities can maintain engagement and reduce perceived stress. However, the mixed feedback regarding the meditation and library scenes highlights the need for careful calibration of content complexity and sensory input to avoid overstimulation or confusion.

Cybersickness emerged as a substantial limitation, with 41% of participants experiencing some discomfort. This proportion is consistent with other VR studies in healthcare contexts and reinforces the importance of optimizing frame rates, headset ergonomics, and motion design to mitigate adverse effects (Deighan et al., 2024). Despite these issues, most participants still rated their experience positively, indicating that the benefits of immersion outweighed the drawbacks for many users.

Interaction effectiveness ratings and feedback also pointed to opportunities for improvement. While the majority of participants could navigate and interact with the scenes successfully, a subset indicated only partial success, often related to unfamiliarity with VR controls or headset adjustments. Enhancing onboarding instructions, simplifying navigation gestures, and providing real-time guidance may help address these usability barriers.

Future work will focus on several areas. First, expanding the study to larger and more diverse participant samples will help validate these findings and explore subgroup differences in response to VR interventions. Second, incorporating longitudinal follow-up can assess whether the positive impacts on willingness to donate translate into actual donation behavior over time. Finally, iterative development will continue to refine content, interaction design, and technical performance to maximize both engagement and comfort.

7. CONCLUSIONS

This pilot study demonstrates that a VR approach can be a promising tool for engaging and educating prospective blood donors. The majority of participants expressed high satisfaction with the experience, and many reported that it reduced their anxiety and increased their willingness to donate. Interactive and visually rich environments, particularly the arcade and art gallery, were especially well received. These findings are consistent with prior studies that have highlighted VR's capacity to improve mood and support health-related behavior change.

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In parallel, the prevalence of cybersickness among participants underscores the need for careful attention to technical optimization and ergonomic design. Usability feedback also indicated opportunities to improve navigation clarity and onboarding instructions to ensure a comfortable and accessible experience for first-time VR users.

In summary, the proposed work contributes to the growing evidence base supporting the role of immersive technologies in healthcare engagement and highlights the potential for VR to become a valuable component of blood donation recruitment and retention strategies.

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