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Virtual Reality Training to De-escalate Patient Aggressive Behavior: A Pilot Study

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ABSTRACT
Despite intensive crisis de-escalation training, psychiatric staff continue to face high injury rates from aggressive patient interactions (APIs). New approaches are needed to enhance the application of effective strategies in managing APIs. This study explored the efficacy and feasibility of VR training for psychiatric staff in recognizing and selecting appropriate de-escalation interventions. A quasi-experimental design with psychiatric staff ($N = 33$) tested the effectiveness and feasibility of VR training depicting a common API interaction. Effectiveness was assessed through pre-post comparisons of the Confidence in Coping with Patient Aggression (CCPA) survey, correct answer percentages, response times, and attempt success rates. Feasibility was indicated by mean scores above 'neutral' on usability, presence, and learner satisfaction surveys. Results showed significant improvements in response times and confidence ($p < .0001$), with over 75% of participants rating the training positively. VR training is effective and feasible for enhancing de-escalation skills, offering a promising approach for psychiatric facilities.

KEYWORDS
Virtual reality; training; pediatric psychiatry; patient aggression; healthcare

1. Introduction

Dysregulated emotional outbursts, reactive aggression, and self-injurious behaviors are common in psychiatrically hospitalized patients. Among psychiatrically hospitalized pediatric patients, aggressive behaviors are highly prevalent, with rates of 23–50% in adolescents (Barton et al., 2001; Barzman et al., 2011; Dean et al., 2008; Ryan et al., 2004) and as high as 58–76% in children (Crocker et al., 2010; Garrison et al., 1990). Management of psychiatric patient aggression or self-harm behavior commonly includes the use of physical seclusion or restraints (Crocker et al., 2010) which involve confining a patient alone in a room, securing the patients' limbs to a bedframe, or holding a patient in a fixed position respectively. Seclusion and restraint of patients are coercive measures associated with psychological trauma, injury, and fatality (Greene et al., 2006; Mohr et al., 2003; Weiss et al., 1998) for patients and staff (Cusack et al., 2018; Lancaster et al., 2008; National Collaborating Centre for Nursing & Supportive Care UK, 2005; Renwick et al., 2016). Further, a significant proportion of employee injuries occur during seclusion and restraint practices. Employee injury due to patient aggression in pediatric settings is concerning, with staff reporting physical injuries from aggressive behavior as the number one cause of injuries (Derscheid & Arnetz, 2020). The United States Bureau of Labor Statistics reports that in 2018, nearly 73% of all nonfatal assaults and violent acts occurred in the healthcare and social assistance industry (Lefèvre-Utile et al., 2018; U.S. Bureau of Labor Statistics, 2018).

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Despite implementing intensive, standardized training in crisis de-escalation protocols, psychiatric staff continue to experience high rates of injury due to aggressive patient interactions (APIs). Staff members frequently encounter potentially volatile situations that require quick thinking and decision-making, de-escalation skills, and empathy. Traditional training methods, while valuable, often do not fully capture the nuanced and dynamic nature of these interactions nor provide the realism scenarios in which to test the required skills. Inadequate preparation and training are significant contributors to staff turnover and injury when working with aggressive patients. Without proper training, staff may feel ill-equipped to handle violent situations, leading to increased stress and job dissatisfaction (Khatri et al., 2023). Additionally, insufficient training can lead to an increase risk of injuries, as staff may not know how to effectively de-escalate aggressive behavior or protect themselves during violent incidents (McDonnell et al., 2023). This lack of confidence and preparedness can result in higher turnover rates as employees seek safer and more supportive work environments (McDonnell et al., 2023). Comprehensive training programs are essential to ensure staff safety, reduce turnover, and improve overall patient care (Goniewicz et al., 2021).

The need for effective training approaches is critical to provide mental health staff a safe space to practice newly learned skills and make mistakes. These approaches should include practice in verbal de-escalation techniques and the ability to recognize and implement alternative interventions prior to resorting to patient seclusion or physical restraint. Without additional training strategies to develop competency in a safe environment to avoid APIs, staff will not be adequately prepared or effective in managing patients with aggressive behavior in mental health settings.

Virtual reality (VR) is a computer-generated simulation that offers an immersive, safe, and controllable environment where mental health professionals can practice de-escalation techniques and refine their skills in a more realistic setting without risk to themselves or patients. VR has been used for training in many different domains including medical, safety, education, and industrial sectors (Abich et al., 2021; Checa & Bustillo, 2020) and can help acquire new knowledge and develop skills, along with enhancing skills already possessed by the user. VR can provide immediate feedback to promote self-correction (Haque & Srinivasan, 2006) and can be used for teaching more than just physical skills: it can also help acquire social and communication skills (Ben Youssef et al., 2015; Bosse et al., 2016; Broekens et al., 2012; Hays et al., 2012) and foster empathy by providing visual and emotional representations of experience (Tang et al., 2024; Trevena et al., 2024). Finally, VR-based training can be standardized, repeated and adjusted to varying difficulty levels, ensuring consistent and comprehensive skill development. Compared to instructor-led training, VR is associated with improved learning knowledge and faster knowledge retrieval (Abich et al., 2021; Webster, 2014).

Prior studies examining the use of VR training in mental health have focused on using VR for therapeutic applications (Geraets et al., 2024; González Moraga et al., 2024; Klein Tuente et al., 2020; Steen et al., 2024); de-escalation training but limited to examining confidence and motion sickness (Johnson et al., 2024); while others only examined usability and qualitative analysis of post-training comments (Moore et al., 2022). Notably, this past research was only with adult patients. To address this specific gap in research for working with pediatric psychiatric patients we developed a VR training module depicting a commonly encountered API to pilot-test this method for effectiveness and feasibility.

2. Methods

This pilot study explored whether VR training offers preliminary indications of efficacy and feasibility in preparing mental health staff to manage and de-escalate aggressive patient behaviors in a high-risk situation. A multidisciplinary team of advanced clinicians, including psychologists, registered nurses, and certified Therapeutic Crisis Intervention (TCI) (Cornell University, 2021) training consultants, systematically identified common scenarios of patient escalation and developed a script to ensure authenticity and face validity. TCI training is designed to help caregivers and educators effectively manage and prevent crises involving children and adolescents. Fundamentals of TCI training emphasize the phases a patient goes through in a typical crisis: baseline behavior, a triggering event, the escalation phase, patient outburst, and recovery.

The script followed the TCI stress model of crisis, with simulated patient's behavior progressing from a "triggering event" associated with agitation ("escalation phase") to more pronounced aggressive and potentially violent behavior ("outburst phase"). The training scenario required participants to identify the appropriate phase of the TCI stress model of crisis (e.g., level of agitation) and select appropriate interventions while interacting with the simulated patient. Embedded within the scenario were targeted questions designed to assess participants' knowledge, situational recognition, and the application of corresponding interventions and techniques tailored to the evolving simulated patient's behavior.

With this content, The University of Cincinnati's Extended Reality (XR) Laboratory developed the training VR training module. Using a quasi-experimental design, we assessed effectiveness and feasibility by implementing the training at two time points. We included a mixed sample of 33 behavioral health specialists (BHSs), behavioral health facilitators (BHFs: similar to a BHS but with additional administrative duties), and registered nurses (RNs) working on adolescent units at an 83-bed inpatient pediatric psychiatric program housed within a large academic medical center. Institutional Review Board approval (ID#2023-0349) was obtained prior to study activities. A consent waiver was granted since the study posed no more than minimal risk and did not negatively impact the rights and welfare of participants. Verbal informed consent was obtained from all participants.

We assessed the effectiveness of each training session by responses from participants on the Confidence in Coping with Patient Aggression (CCPA) (Thackrey, 1987) and VR platform statistics including: percentage of correct answers on the first attempt; time to the correct answer; and the number of successful and unsuccessful attempts. The difference in CCPA responses and VR platform statistics between the first and second training sessions provided additional insight into the impact of repeated VR training.

Overall positive feedback from participants on user usability, presence, and learner satisfaction provided the indicators for the feasibility of the VR training module. We also assessed feasibility by asking participants "What part of the training session did you find the most beneficial?" and requesting other open-ended comments about the training. We obtained Institutional Review Board approval prior to all study activities.

3. Study group

Participants were recruited among BHSs, BHFs, and RNs assigned to the unit through presentations at staff meetings, flyers, and by individual interactions. Prior to enrollment we stratified potential participants by: sex (Male/Female); job experience (high $\geqq 1$ year, low <1 year); and prior VR experience (yes/no). All participants were required to have at least five patient restraints to ensure sufficient experience with the procedure. We aimed at enrolling a target number of five participants per subgroup (total expected $N = 40$).

3.1. Module development

To produce the module, we followed a standard VR training development process. This process begins with conceptual design, defining objectives, and collaborating with subject matter experts to ensure contextual and medical accuracy. The story and script development phase involves crafting realistic narratives through collaboration with an interdisciplinary team of experts including: a psychologist, a psychiatric nurse, and two education specialists, all of whom bring substantial experience in direct patient care and training within acute inpatient settings. Their collective expertise ensures the incorporation of challenging scenarios and complex decision-making situations that foster meaningful learner engagement. The content developed during this phase was thoroughly validated by these subject matter experts to ensure clinical accuracy and educational relevance. In the subsequent modeling and animation phase, detailed 3-dimensional (3D) models and characters are created and animated to simulate realistic interactions, further enhancing the immersive learning experience.

These assets are then integrated during VR integration and user-interface (UI) development, where an intuitive UI ensures seamless interaction within the VR environment. Intermediate usability testing

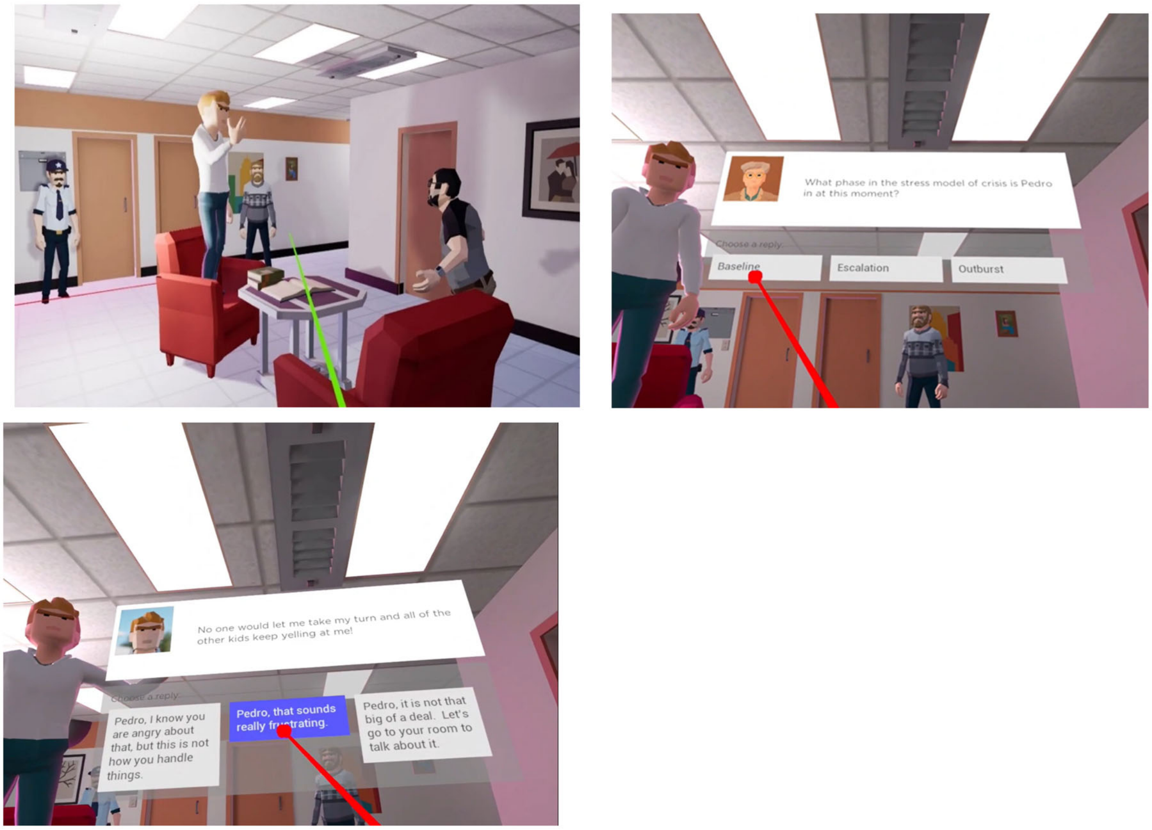

Figure 1. Screenshots of the VR training module running on the standalone mobile VR headset. A cartoonish visual style was used to create the animated characters and environment. Users interact using motion controllers, which simulate a laser pointer for making selections in the VR environment.

follows, gathering feedback from a sample group not included on the study, to refine the user experience.

The module development process began with reality capture, which involved site visits to the adolescent psychiatric units and digitalization of the physical environment through scanning. The captured data served as a reference for creating 3D models in Autodesk Revit. These 3D models, along with digital avatar character models, were then imported into Unreal Engine (Epic Games, Inc™, Cary, NC), a platform for developing interactive 3D graphics and immersive VR experiences. Within Unreal Engine, we added materials, lighting, and interactive elements to enhance the environment. The animated characters – including a simulated teenage patient and several staff members – were designed in a low-polygon, cartoonish style rather than a photorealistic one (Figure 1). This approach was chosen for two main reasons: (i) to maintain a low polygon count that enables higher frame rates on mobile VR devices, such as the standalone Quest 2 headset; and (ii) to avoid the "uncanny valley" effect, which can provoke discomfort in users when encountering highly realistic but imperfect digital humans in games or films. Subsequently, we integrated UI design, dialogue systems, animations, voices, and programming within Unreal Engine to create the final scenario and tools for real-time data capture.

4. The API scenario

The virtual environment was meticulously constructed to replicate the exact dimensions and spatial layout of the actual inpatient unit, incorporating features such as lighting, furniture, and interior materials. This effort aims to create a highly accurate digital twin of the physical environment. To ensure optimal performance and an immersive user experience, the model was carefully optimized in Unreal Engine for VR display. Optimization techniques included reducing polygon counts, creating multiple levels of detail (LOD), and pre-baking lighting and shadows. These methods enabled high frame rates and a smooth VR experience on the standalone Quest 2 headset.

The VR training simulated a commonly experienced scenario on an inpatient adolescent unit following script written by the interdisciplinary team responsible for staff training and consultation with direct care staff. The model begins with the participant being "placed" in a simulated adolescent unit where a VR coach is describing the scenario. The participant is then presented with a scene depicting a patient standing on a chair and exhibiting increasing agitation and aggressive behaviors (e.g., yelling, indirect verbal threats). Participants completing the module by responding to and navigating through a progression of escalated verbal and nonverbal behaviors exhibited by the patient. At predefined stages, participants respond to multiple-choice questions (seven in total) that prompt recognition of the level of behavioral escalation followed by identifying the appropriate intervention (response to patient behavior) to implement at that level, matching principles of the formal TCI de-escalation protocol in which they had been trained. Questions and responses were presented within the VR simulation with the participant selecting from multiple choice question and responses (presented visually and audibly) using the hand controller with a "laser-pointer" method. When incorrect responses were selected, participants were informed of the error and presented with the multiple-choice options again until the optimal response was selected. Following selection of the optimal response, the VR simulation continues with the patient responding to the chosen response and exhibiting additional behaviors for the next stage and set of questions. This process continues until the participant successfully de-escalates the patient. All participants experienced the exact same scenario (i.e., same set of questions and patient behaviors) across trainings and time points. Questions within the VR simulation were directly parallel to questions and vignettes used in bi-annual trainings. Including formal crisis de-escalation training in a VR module is particularly novel, enhancing realism, ability to examine staff knowledge while providing safe, repeatable practice scenarios.

5. VR training data capture

We captured user performance data throughout the VR training session. The system recorded users' choices, response times, and timestamps, providing detailed data for analysis. The data capture system was developed using Unreal Engine's Blueprint scripting and customized C++ programming. It enables the recording of runtime user data into external CSV files, which can be accessed and analyzed after the VR training session.

6. Study procedures

Once enrolled, we administered two baseline surveys: the first collected demographics (age, sex, gender, and race) and VR experience; the second survey was the Confidence in Coping with Patient Aggression (CCPA) (Thackrey, 1987) assessing self-efficacy in managing and responding to aggressive patient behavior using a scale from 1 – "very uncomfortable" to 7 – "very comfortable." The study team then provided standardized instructions and reviewed procedures with each participant providing brief training and orientation on the VR headset (Meta Quest 2), controls, and operation. The team also informed participants to remove the headset at once and discontinue the training immediately if they experienced discomfort or dizziness.

Participants engaged in the training at two time points, at least 3 weeks apart, and prior to the institution's bi-annual patient crisis de-escalation training. After each session, they completed four surveys; the CCPA; Presence (Witmer & Singer, 1998) to measure the extent to which an individual feels immersed in a virtual environment as if it were real ("not at all" – "completely"); usability [a modified System Usability Scale (SUS), excluding question 5 and 6 from the original] (Brooke, 1996) with responses ranging from "strongly disagree" to "strongly agree"; and an investigator-developed learner satisfaction survey consistent with standard practices for evaluating workplace learning in educational programs (Rivera & Paradise, 2006) with responses ranging from "strongly disagree" to "strongly agree."

6.1. Statistical analysis

We used descriptive statistics to summarize participant demographics and other characteristics. Frequency and percentages are provided for categorical variables; mean, standard deviation, median, quartiles, minimum and maximum were used for continuous variables. Comparisons of outcomes between training at the first and second time points are made through generalized linear mixed-effect models with a participant random intercept. The unadjusted model included the time variable as the only fixed effect, while the adjusted model included sex, job experience, and VR experience as covariates. We used the negative binomial distribution with log link function for count outcomes and Gaussian distribution with identity link function for continuous outcomes. Changes in response direction between surveys are summarized using N and percentages. We conducted a 2-sided exact binomial test for the hypothesis that increasing direction is different from 0.5 for each survey question. Two sided exact Clopper-Pearson 95% confidence intervals (CI) are provided; a p-value <0.05 is considered statistically significant; no multiple testing adjustments were done; and we used SAS 9.4 software (SAS Institute, Cary, NC, USA) for analysis.

We assessed effectiveness of the VR training by the mean responses to the CCPA along with the metrics automatically collected within the VR training platform, specifically the percentage of correct answers on the first attempt, the time (in seconds) to correct answer, and the number of successful and unsuccessful attempts at answering a question. The difference in CCPA responses between baseline and after the first training provided a preliminary assessment of the impact of the training module. The difference between the VR platform statistics and after the first and the second session provided an assessment of the impact of repeated VR training.

In this pilot study, we wanted to gather preliminary evidence that the VR training was acceptable to the majority of participants and produced effects that would be testable in a larger-scale controlled trial. We deemed the VR training feasible if 75% of the participants reported a mean score above "neutral," the mid-point of the scale range on the SUS, presence, and learner satisfaction surveys. Given the high level of experience of the participant group, a majority indicating satisfaction would provide adequate evidence that the VR training could be used at a larger scale for training purposes and formally tested in a trial with a control arm. The mean rating of all questions in each survey was calculated by averaging all the items in the survey for each participant. We then compared the average rating with the neutral rating to compute the percentage of respondents with a greater-than-neutral average score.

7. Results

Thirty-three direct care staff participated in the first training session and 30 in the second training session. Participants were 23 unlicensed direct care staff (BHSs and BHFs) and 10 direct care RNs. Work experience was measured by the number of years working in their current position, with 45.5% of participants working less than one year. Most participants (69.7%) had little to no VR experience (Table 1). The average time to complete the VR training session was 6.74 min (SD = 1.5, and a range of 3.78–12.5 mins).

No hardware limitations were observed, and participants were informed during pre-study training that they could discontinue participation if they experienced any discomfort or dizziness related to VR use. None chose to discontinue participation.

8. Effectiveness

Compared to the first training, the second training session there was a slight decrease in the number of incorrect answers (average: 1.4 at the first training, 1.2 at the second) and first-attempt correct answers (average: 5.7 at the first training, 5.6 at the second training) but these differences were not significant (Table 2). Notably, the second training session required significantly shorter time (average: 441.4 sec at the first training, 362.9 at the second).

Before VR training, the percentage of greater-than-neutral Confidence in Coping with Patient Aggression (CCPA) scores was generally very high, ranging from 84.8 to 90.3% (Table 3). Results of the CCPA scores showed a significant increase from baseline to the first VR training session

Table 1. Demographics of the study cohort.

Demographics	($N = 33$)	Missing from second training ($N = 3$)
Age group		
18–25 Years old	13 (39.4%)	1
26–35 Years old	11 (33.3%)	1
36–45 Years old	7 (21.2%)	1
46–55 Years old	2 (6.1%)	
Sex		
Female	21 (63.6%)	2
Male	12 (36.4%)	1
Self-identified gender		
Female	19 (57.6%)	2
Gender variant/Non-conforming	2 (6.1%)	
Male	10 (30.3%)	1
Transgender male	2 (6.1%)	
Race ethnicity		
Asian	1 (3.0%)	
Black or African American	8 (24.2%)	1
More than one race	4 (12.1%)	
White	20 (60.6%)	2
Current position		
BHF	12 (36.4%)	
BHS	11 (33.3%)	2
RN	10 (30.3%)	1
Years in current position		
Less than 1 year	15 (45.5%)	1
More than 1 year	18 (54.5%)	2
VR experience		
Expert	3 (9.1%)	1
Somewhat experienced	7 (21.2%)	1
A little experience	10 (30.3%)	1
No experience	13 (39.4%)	

Table 2. VR platform training metrics.

VR results	First training session ($N = 33$)	Second training session ($N = 30$)	Unadjusted p-value*	Adjusted p-value*
Overall results				
Total number of times incorrect answers were chosen for Question 1–7			0.4504	0.4859
N	33	30		
Min-Max	0.0–4.0	0.0–3.0		
Mean (SD)	1.4 (1.23)	1.2 (0.89)		
Median (Q1, Q3)	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)		
Number of correct answers in the first try for Question 1–7			0.9561	0.9374
N	33	30		
Min-Max	3.0–7.0	4.0–7.0		
Mean (SD)	5.7 (0.89)	5.6 (0.67)		
Median (Q1, Q3)	6.0 (5.0, 6.0)	6.0 (5.0, 6.0)		
Total time in seconds answering all 7 training questions			<0.0001	<0.0001
N	33	30		
Min-Max	320.1–749.2	227.3–456.7		
Mean (SD)	441.4 (100.00)	362.9 (56.11)		
Median (Q1, Q3)	420.5 (397.6, 450.8)	353.4 (326.4, 411.0)		

for: comfort working with an aggressive patient, assessing present level of training for handling aggression, self-assuredness, and ability to intervene psychologically with an aggressive patient with the percentages of greater-than-neutral scores approaching 100%. There was little change in CCPA scores after the second training session. Only "self-assuredness in the presence of an aggressive patient" showed a significant improvement in the adjusted model after the first training session.

9. Feasibility

All surveys had more than 75% participants (our threshold) and nearing 100%, with a mean score greater than neutral (Table 4). Presence and learner satisfaction scores decreased after the second

Table 3. The percentage of participants with CCPA scores greater than neutral.

Survey items	Pre-training % Mean (SD)	Post training Mean (SD)	2nd Post training Mean (SD)	Unadjusted *p*-value* Pre vs. post	Adjusted *p*-value* Pre vs. Post	Unadjusted *p*-value* Post vs. 2nd post	Adjusted *P*-value* Post vs. 2nd post
How comfortable are you in working with an aggressive patient?	90.9% 5.9 (1.34)	97.0% 6.3 (0.88)	100.0% 6.3 (0.78)	**0.0456**	**0.0456**	0.7891	0.8224
How good is your present level of training for handling psychological aggression?	90.9% 5.8 (0.96)	100.0% 6.2 (0.80)	100.0% 6.3 (0.69)	**0.0031**	**0.0031**	0.2286	0.2159
How able are you to intervene physically with an aggressive patient?	84.8% 5.9 (1.52)	87.9% 6.0 (1.37)	86.7% 6.0 (1.29)	0.4880	0.4880	0.7418	0.7162
How self-assured do you feel in the presence of an aggressive patient?	87.9% 5.9 (1.14)	97.0% 6.2 (0.87)	93.3% 6.0 (0.95)	**0.0101**	**0.0101**	**0.0464**	**0.0434**
How able are you to intervene psychologically with an aggressive patient?	90.9% 5.9 (1.09)	97.0% 6.2 (0.85)	100.0% 6.3 (0.71)	**0.0184**	**0.0184**	0.1427	0.1398

*Generalized linear mixed-effect models were used with random interception for each subject. The unadjusted *p*-value was from a model where the training session was the only independent variable. The adjusted *p*-value was from a model where sex, work experience, and dichotomized VR experience (none vs. any) were included as covariates. Bold values indicate statistical significance.

Table 4. Percentage of participants with greater than neutral MEAN rating of all questions within each survey.

Domain	Pre-training*	1st Training (%)	2nd Training (%)
CCPA	93.9%	100.0	100.0
Presence	——	97.0	96.7
Satisfaction	——	100.0	96.7
Usability	——	93.9	96.7

*Only the CCPA was administered pre-training as the remaining. Surveys relied on participation in the VR training.

training session, with usability being the only metric that increased. Nearly all participants (96.7%) would recommend the VR training to other staff, and 90% agreed to participate in future trainings after the second training session.

Cronbach's alpha for the CCPA, presence, and learner satisfaction surveys ranged from 0.7–0.93, and the SUS was 0.66.

Table 5 shows the percentage of scores that were greater than neutral for each survey item. The most notable increase in CCPA scores occurred after the first training with the majority of items showing consistency or a slight increase in improvement after the second training. There were noticeable improvements in immersion scores from the presence survey, between the first and second training session, ranging from 2.4 to 11.9%. Improvement was seen in focusing on the tasks rather than on the VR equipment; engaging senses; and if participants felt completely focused on the task or environment. We noticed decreases in scores in responsiveness of the VR environment and how natural the interaction seemed in the VR environment.

Usability scores after the first training session were promising; however, there were noticeable declines in positive scoring after the second training. Decreases in whether the training would help participants better interact with aggressive patients and ease of use. Overall learner satisfaction scores greater than neutral were above 85%, excluding the question regarding increase in confidence in interacting with an aggressive patient (63.6%). Over 85% of participants at the first and second sessions would recommend the training to their colleagues and would be willing to participate in future virtual reality trainings.

Participant responses to open-ended questions (Table 6) showed an appreciation of the life-like content and environment and the ability to experience an aggressive patient interaction in a safe environment: "I enjoyed the fact that it was a real-life scenario"; "Being in the VR versus a real physical environment provided opportunity to de-escalate without having the actual stress and time pressure as a real escalation." Participants deemed the training module to be "surprisingly immersive" and stated that "multiple of these scenarios can help build confidence in approaching escalated patients."

10. Discussion

Virtual reality (VR) and other digital simulation technologies have emerged as promising tools in psychiatric training, enabling safe, immersive, and repeatable scenarios that mirror real-life aggressive encounters in clinical settings (Herbst et al., 2021; Pedersen & Musaeus, 2023). VR training provides an immersive, controlled environment where staff can practice de-escalation techniques without the risks associated with real-life incidents. Evidence supporting the efficacy and feasibility of VR training programs has been observed in multiple studies, which have reported enhanced learning outcomes, increased staff confidence, and improved patient interactions following such training (Abich et al., 2021; Elendu et al., 2024). In accordance with prior VR training studies, this pilot study on the use of VR training, in an immersive, realistic environment, to enhance pediatric mental health staff's ability to de-escalate aggressive patients has shown promising results in terms of effectiveness and feasibility. This notion is reflected in our participants' open-ended responses; "I fell that this is a good way to get a feel for how a crisis situation would look;" "Being in the VR versus a real physical environment provided opportunity to de-escalate without having the actual stress and time pressure as a real escalation." This innovative approach addresses a critical need in mental health settings, where staff often face challenging and potentially dangerous situations.

Table 5. Individual scores greater than neutral within each survey.

	Pre-training (%)	1st Training (%)	2nd Training (%)
CCPA			
How comfortable are you in working with an aggressive patient?	90.9	97.0	100.0
How good is your present level of training for handling psychological aggression?	90.9	100.0	100.0
How able are you to intervene physically with an aggressive patient?	84.8	87.9	86.7
How self-assured do you feel in the presence of an aggressive patient?	87.9	97.0	93.3
How able are you to intervene psychologically with an aggressive patient?	90.9	97.0	100.0
Presence			
How responsive was the virtual environment to actions that you initiated (or performed)?		93.9	86.7
How natural did your interactions with the virtual environment seem?		78.8	76.7
How much did your experiences in the virtual environment seem consistent with your real-world experiences?		87.9	90.0
How involved were you in the virtual training environment?		90.9	90.0
How quickly did you adjust to the virtual training environment?		97.0	100.0
How much did the visual display quality interfere or distract you from performing tasks or activities?*		42.4	16.7
How well could you concentrate on the tasks or activities rather than on the mechanisms used to perform those tasks or activities?		84.8	96.7
How completely were your senses engaged in this virtual training environment?		90.9	93.3
Overall, how much did you focus on using the display and control devices instead of the virtual training?*		45.5	36.7
Were you involved in the virtual training to the extent that you lost track of time?		45.5	50.0
Were there moments during the virtual training when you felt completely focused on the task or environment?		81.8	86.7
How easily did you adjust to the control devices used to interact with the virtual environment?		97.0	93.3
Usability			
This training will help me to better interact with aggressive patients		78.8	76.7
I found the training unnecessarily complex*		3	6.7
The training program easy to use		97.0	93.3
I would need the support of a technical person to be able to use this training*		33.3	23.3
I would imagine that most people would learn to use this training very quickly		87.9	93.3
I found the training program very cumbersome to use*		21.2	16.7
I felt very confident using the training		90.9	90.0
I needed to learn a lot of things before I could get going with this training*		12.1	3.3
Learner satisfaction			
The training was effective in identifying strategies to use in patient de-escalation		87.9	93.3
The training was effective in recognizing stages of crisis in the inpatient setting		97.0	93.3
The training was effective in experiencing a crisis situation in a virtual environment		97.0	93.3
The training included important TCI skills used in my job		90.9	96.7
The training increased my confidence for interacting with an aggressive patient		63.6	66.7
I can apply what I learned from the training to my job		93.9	93.3
I intend to apply what I've learned from the training to my job		90.9	96.7
This session will help me to interact with an aggressive patient more effectively		90.9	76.7
I was satisfied with the quality of the virtual reality training session.		93.9	100.0
I would recommend this training to other staff		87.9	96.7
I would like to participate in future virtual reality trainings		97.0	90.0

*Questions were reversely scored.

Table 6. Responses to "what part of the training session did you find the most beneficial?"

"I thought that it was helpful that the training gave me direct feedback to tell me what I am doing wrong."
"I fell that this is a good way to get a feel for how a crisis situation would look."
"It felt exactly like a scenario I would encounter on the floor, and it gave a great way to try to de-escalate [the] pt even though he still entered outburst phase."
"Being able to safely interact with an aggressive patient."
"I enjoyed the fact that it was a real-life scenario. Other staff being present and being told the back story was helpful."
"Being in the VR versus a real physical environment provided opportunity to de-escalate without having the actual stress and time pressure as a real escalation."
"Being able to see myself in real time respond to an escalated situation."
"Being able to engage with what felt like a real scenario you could encounter on the unit."
"Getting to experience pt aggression as close to real life as possible in order to sit with any uncomfortable emotions that might come up within a staff member who is face to face with an aggressive pt."

Open-ended comments:

Category	Response
Immersion & realism ($N=2$)	"Surprisingly immersive. I would recommend adding more scenarios under various circumstances." "Overall, the training seemed to be a good approach that would show a realistic scenario. I think multiple of these scenarios can help build confidence in approaching escalated patients. The headset and controllers were easy to adapt to using and it was not too complex of technology to adapt to. It did sometimes feel a bit robotic but it did not take much away from the experience."
Educational value ($N=2$)	"This could be very helpful when it comes to helping others how to best respond in a crisis." "Feel as though this would be a helpful tool to teach the crisis escalation model."
Clarity & communication ($N=1$)	"This experience was great, sometimes on tests words or phrases can be interpreted incorrectly which causes a staff to get confused. With viewing the circumstances, it makes it easier to identify the answer."

As indicated in the Methods section, we wanted to gather preliminary evidence that the VR training was acceptable to the majority of participants and produced effects that would be testable in a larger-scale controlled trial. We set a simple a priori feasibility criterion: 75% of the participants reporting a mean score above "neutral." We stated the criterion before gathering data, and the results met the criterion. As the participant group was already experienced, we interpret these results as evidence that the VR experience could be used at the scale required for a trial with a control arm. The results of this study also provide testable effects, both in terms of improved response times after training, and in terms of improvement in confidence in coping with aggressive patients. Thus, our results provide critically important elements for designing a well-powered randomized trial of VR training vs. standard TCI training.

Several studies have indicated that VR simulations can replicate high-stress situations with enough realism to elicit authentic emotional and physiological responses, which are essential for effective learning (Kothgassner et al., 2023). This realistic exposure allows staff to practice decision-making, communication skills, and emotional regulation in response to aggressive patient behavior, which are crucial skills for de-escalation in psychiatric settings. Overall, in the current study, responses to the survey presence assessing realism and immersiveness, revealed that the VR training module was consistent with real-world experiences (first training: 87.9%, second: 90.0%) and participants were involved in the VR environment (both sessions 90.9%). Open-ended responses stated that [the training] was "surprisingly immersive," and that "it felt exactly like a scenario I would encounter on the floor" supported the immersive nature of the VR training content.

Studies support the idea that repeated practice in VR enhances skill retention and situational awareness in high-stakes environments (Gasteiger et al., 2022). In the present study, in-training metrics of incorrect and correct answers on the first attempt did not show significant improvement between the first and second training sessions. However, the speed with which a correct answer was selected improved significantly (mean 441®362.9 s $p<.0001$), a critical skill regarding tactical decision-making in a crisis situation (Rubinstein, 2013). In addition, only "self-assuredness in the presence of an aggressive patient" was significant in the adjusted model and the ability to intervene physically with an aggressive patient was not significant. To accurately predict one's ability to intervene with a physically aggressive patient is challenging until faced with such a situation in real life and may not be fully replicated in a virtual environment.

As this was a pilot and the same straightforward scenario was depicted at each session, it is possible learning at the first VR training was highly effective, but little was left to be learned at the second attempt, particularly among experienced staff participants. This phenomenon is due to the practice effect (Jackson & O'Callaghan, 2009) where improvements are limited after repeated training due to the ceiling effect, where the module was not challenging enough and encompasses both increased familiarity with the simulation format and potential memorization of scenario elements, so scores plateaued or even decreased with repeated sessions (Liu & Wang, 2021). Future trials with more complex and involved modules are necessary to cover the variety of crisis situations that require mastering de-escalation. Such trials may show more clearly the benefit of repeated training sessions. Comprehensive exposure may better prepare staff for real-life situations compared to training modules that are limited in scope and variability. By gradually introducing staff to escalating scenarios in a controlled environment, VR training helps them develop confidence and emotional resilience, essential qualities for maintaining composure during real incidents.

The implementation of our pilot VR training was found to be feasible by the participants. The VR scenario was reported as realistic and engaging, which facilitated a high level of immersion and prompted individuals to say they would recommend the training to colleagues and participate in future sessions. The technology was user-friendly, and the training sessions showed a high level of learner satisfaction scores regarding strategies for patient aggression de-escalation and applicability. These findings align with previous research indicating that VR training can be seamlessly incorporated into healthcare settings, providing a flexible and scalable solution for continuous professional development (Herbst et al., 2021; Kouijzer et al., 2023; Steen et al., 2024).

Further research is needed to build on these findings and optimize the use of VR in professional training programs. Our future studies will explore the long-term impact of VR training in psychiatric units on the transition of skills to practice; employee outcomes such as injuries due to APIs and staff retention; as well as patient outcomes such as seclusions and restraints. As VR technology continues to evolve, its integration into psychiatric training programs has the potential to transform how mental health professionals approach and manage aggression in clinical settings.

11. Limitations and conclusions

While the results of this study are promising, there are some limitations to consider. The short timeframe is seen as a limitation in the current research and is necessary to assess the durability of the skills acquired through VR training. While VR training shows promise for mental health applications, there is a clear need for well-designed, longitudinal studies to evaluate its effectiveness not only on skills but on employee and patient outcomes, e.g., reduction in employee injuries due to aggression; improved employee retention; and a reduction in patient seclusions and restraints due to successful de-escalation. Aside from in-training metrics, our results were derived from self-reported measures. While user experience, satisfaction, and acceptability are key when implementing new training interventions, objective measures are valuable to ascertain effectiveness. Finally, the sample size was relatively small, and the study was conducted in a single mental health facility limiting generalizability. Future research should aim to replicate these findings across multiple sites, complex patient scenarios, and with larger sample sizes.

This study provides promising evidence for the effectiveness and feasibility of VR training in improving psychiatric staff's de-escalation skills. The immersive and interactive nature of VR technology offers an unique and powerful tool for enhancing confidence and practical skills in managing aggressive patients. As mental health facilities continue to seek innovative ways to improve patient care and staff safety, VR training represents a promising avenue for future development and implementation.

Author contributions

CRediT: **Nancy M. Daraiseh**: Conceptualization, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing; **Ming Tang**: Software, Writing – review & editing; **Maurizio Macaluso**: Conceptualization, Methodology, Writing – original draft, Writing – review & editing; **Madeline Aeschbury**:

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Ethical approval

Approval was gained from Cincinnati Children's Hospital Medical Center's Institutional Review Board. The study was deemed exempt. IRB ID: 2023-0349. A consent waiver was granted since the study posed no more than minimal risk and did not negatively impact the rights and welfare of participants. Verbal informed consent was obtained from all participants.

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Data availability statement

Deidentified individual participant data will not be made available.

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