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RESEARCH ARTICLE

Cognitive and physiological evaluation of virtual reality training in nursing

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ABSTRACT
Virtual reality (VR) has increasingly been used in several disciplines, including nursing, a profession in high demand that is now facing a shortage. This study investigated the effectiveness and efficacy of VR hybrid training over traditional training (TR) methods. Sixteen college students were recruited and randomly assigned to get 100% TR or 50% TR and 50% VR (VR50). Participants attended a three-day program with a registered nurse, consisting of lectures and practical lab sessions. Participants' performance, training time, cognitive development, physical development, mental workload, user experience, Students' Satisfaction and Self-Confidence, and team learning were evaluated. The results showed that the VR50 performed as well as, and sometimes even better than the TR group (p-value = 0.043). VR50 group significantly had higher cognitive development and found VR easy to use and attractive (p-value < 0.05). VR-integrated training makes nurses' training more affordable and accessible while providing instant and relevant feedback.

Practitioner Summary: This study assessed employment-integrated virtual training in nursing, particularly peri-care, by comparing the performance, cognitive, physical, and mental workload of traditional and integrated VR training groups. The findings of this study provide significant support for incorporating VR training into educational settings.

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KEYWORDS
Virtual reality; nursing training; cognitive development; peri-care; simulation

1. Introduction

The United States is grappling with a critical shortage of nurses, as evidenced by Dr. David Auerbach and colleagues' findings, indicating a decrease of over 100,000 in the total supply of registered nurses (RNs) from 2020 to 2021. This reduction represents the most substantial drop observed in the past four decades (Buerhaus et al. 2022). Moreover, projections from the American Journal of Medical Quality indicate that a shortage of registered nurses is anticipated to escalate nationwide through 2030 (Juraschek et al. 2019). The shortage of nurses in the United States is the result of various contributing factors, including low enrolment in nursing schools, a scarcity of faculty, a significant portion of the nursing workforce nearing retirement, and the effects of the ongoing pandemic (American Association of Colleges of Nursing 2022). Also, there is a shortage of certified nursing assistants (CNAs) due to several factors, including a limited number of nursing educators, which results in small class sizes despite the high demand for CNA programs.

Additionally, the quality of programs provided to students presents a barrier to CNAs entering the workforce, contributing to the shortage despite numerous opportunities and demand for CNA positions. Hence, there is a pressing need to expedite the training of RNs and CNAs to address the ongoing shortage in the healthcare workforce. VR technology represents one of the latest advancements, with ongoing efforts to incorporate it into training programs across various fields, particularly in the healthcare sector.

VR defines computer-based technologies that simulate the natural world by stimulating the senses, usually through sight and sound. Once known for its expensive and cumbersome equipment, this branch of technology has seen a surge in consumer-grade VR devices. The increased access to the virtual world has also caused an increase in the creation of applications of VR at a lower cost across a wide variety of subject areas, from personal entertainment to professional development, providing benefits to the participants including but not limited to an increase in cognitive

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skills, psychomotor skills, and physical therapy in the form of limb functional recovery (Xie et al. 2021).

In the world of professional development, VR is a promising tool, too. The cut in cost is one of many advantages VR has over traditional training. There is increased accessibility to subject matter experts, reduced training time, and a smaller, more secure setting for the training, with minimal special requirements and distance from hazardous materials and situations (Lucas, Thabet, and Worlikar 2007). Due to these advantages, researchers investigated VR as a training tool in various fields, with medicine being prominent. Examples of VR training in the medical field include the following: evaluation tools for psychomotor skills needed to perform laparoscopic surgery (Gallagher and Satava 2002), tools of laparoscopic skills (Grantcharov et al. 2004), training tools for orthognathic surgery (Pulijala et al. 2018), instructional technique for catheter insertion (Arslan et al. 2022; Smith and Hamilton 2015), and as a tool for nursing education approach (Ma et al. 2024). Enhancing the training of these skills positively affects not only certified nursing assistants but also the nurses who often oversee and/or perform these procedures. Additionally, the quality of these skills impacts the job of downstream physicians who rely on these procedures being properly performed.

While studies have pointed out the failings of VR (Leighton et al. 2021), such as the limited ability for complex feedback and the lack of the interpersonal nature of working with patients; its contemporaries have found that the use of VR as an additional training tool has great potential. VR was used as a training tool to assess how prepared nurses felt in dealing with disaster. VR was found to improve the nurses' understanding of theoretical concepts and overall satisfaction with their learning, leading them to assess themselves as more prepared for disaster (Magi et al. 2023).

In addition to examining the efficacy and effectiveness of VR technology, researchers have conducted investigations and surveys to gather nursing students' perspectives on the utility of such tools for educational and training purposes. VR was recommended and perceived as a compliment by many students (Saab et al. 2021) and as easy, usefulness (Padilha et al. 2018), and classified as a 'fast skill learning process, stress-free learning environment' (Chang and Lai 2021).

This tool is not limited to disaster training; it can also be effectively applied to other areas of nursing, such as perineal care (peri-care), which involves cleaning care for a patient's private areas. Therefore, this study aims to explore the impact of VR hybrid training and assess its effectiveness compared to traditional training methods.

2. Methods

2.1. Ethics statement

This research complied with the American Psychological Association Code of Ethics. The Institutional Review Board (IRB) at Iowa State University authorised this research to be conducted (22-277-00). On the first day of the study, the participants' informed consent was obtained immediately upon their arrival.

2.2. Experimental materials and setting

To simulate a real-life healthcare scenario, a room on the Iowa State University campus was equipped with all the essential peri-care equipment. Depending on the session, there were four training stations, either traditional or VR.

Each traditional station consisted of three major substations. The first substation was next to the shared sink and contained antibacterial soap, paper towels, and hand sanitiser. The second substation on the side rack was equipped with reusable waterproof mats, hand towel sets, gloves in all sizes (small, medium, large, and extra-large), and basins. The third substation consisted of a hospital bed with mannequins, bed blankets, fitted sheets, pillows, side tables, laundry baskets, trash cans, hand sanitiser, and privacy curtains (Figure 1).

All four stations were of this format for the traditional group, while the VR group had two of these stations in addition to two VR50 Stations. Each VR50 station had a monitor, a streamer, two VR50 headsets (one primary and one backup), and a three-by-three-meter taped space.

VRNA™, developed by VRSim, Inc. ('VRSim'), is an immersive VR that trains Nurse Aides in patient care. With VRNATM, students may enter a VR experience using all-in-one VR technology (i.e. standalone VR headsets) without needing to be connected to a PC or laptop, allowing for more mobility and immersion. Inside the VR environment, trainees physically administer direct care operations to simulated patients by completing kinaesthetic gestures using hand-held controllers. Hence, users can see how hand controller-activated instructions interact with the virtual world. In addition, the virtual hands enable the user to comprehend better the reach/motion of their hands and arms. Based on the results of Barkokebas et al. (2019), user interactions with tools and goals are enhanced to improve the portrayal of a real task in a VR application.

Figure 1. Traditional training.

2.3. Participants

Participants were recruited from Iowa State University using fliers distributed across the campus. An eligibility questionnaire was emailed to interested participants to verify their compliance with the inclusion criteria. Inclusion criteria include being 18 years or above, able to move the head and look around, moving the upper body (arms, hands, fingers), lifting arms (25 lbs.), grasping objects, and walking without assistance or restriction. The exclusion criteria are VR experience, nursing background, CNA lab skills, skin allergy to rubber latex or plastic rubber, and VR or cybersickness history. Participants in this study were split into two separate groups. One got training that consisted of 100% traditional training (TR), while the other received training that consisted of 50% traditional and 50% virtual environment training (VR50).

2.4. Independent and dependent variables

In this research, the critical independent variable was the training type, assessed at two levels to represent the distinct interface types being evaluated: TR and VR50.

This study had six dependent variables: performance (skills evaluation, review quiz, and final written exam), training time, cognitive development, physical development, mental workload (MWL), user experience (UE), and Students' Satisfaction and Self-Confidence shown in Table 1. In addition, team learning was assisted.

This study used Bloom's taxonomy to measure cognitive development. Bloom's taxonomy is frequently employed to evaluate cognitive development. Using Crooks' (1988) critique of Bloom's taxonomy simplified it.

Electromyographic (EMG) feedback for the deltoid, upper trapezius, extensor digitorum, flexor carpi ulnaris, and erector spinae muscles was employed as physical development measures in this research. To obtain a baseline value that is typical of each participant's maximal voluntary muscular contraction, a maximum voluntary contraction (MVC) was carried out on each of them.

The NASA Task Load Index (Hart 2016) was adopted as the MWL evaluation tool since it is a subjective multi-dimensional measure.

An analysis of the user experience questionnaire (UEQ) was carried out according to the training type. It should enable users to convey thoughts, perceptions, and attitudes that develop from experiencing the training type under consideration straightforwardly and rapidly.

Table 1. Measures of dependent variables and individual participant characteristics during experiment.

	Time of administration					
	Day 1		Day 2		Day 3	
Questionnaire	Pre-training	Post-training	Pre-training	Post-training	Pre-final skill evaluation	Post-final skill evaluation
Consent form	×					
Demographics	×					
Skills evaluation 1		×				
Skills evaluation 2				×		
Quiz 1		×				
Quiz 2				×		
Final written exam						×
Bloom's taxonomy (Bloom et al. 1956)						×
Muscle activity						×
MWL (Hart 2016)						
UE (Laugwitz, Held, and Schrepp 2008)						×
Students' satisfaction and self-confidence						×
SSQ (Kennedy et al. 1993)	×	×	×	×		

The Students' Satisfaction and Self-Confidence Questionnaire consists of items concerning the participants' views towards the teaching they get throughout their simulation activity. The American Nursing Association created it based on Pamela Jeffries' nursing education simulation paradigm, including two subscales to measure students' satisfaction (five measures) and self-confidence (eight measures) while utilising manikins to address clinical scenarios following learning in simulation rooms. The participant was required to assess their confidence and satisfaction using a 5-point Likert scale, ranging from 0 for strongly disagree to 5 for strongly agree (Adamson, Kardong-Edgren, and Willhaus 2013).

Participants were asked to fill out a Simulator Sickness Questionnaire (SSQ). This questionnaire includes 16 symptoms: General Discomfort, Fatigue, Headache, Eye Strain, Difficulty Focusing, Increased Salivation, Sweating, Nausea, Difficulty Concentrating, Fullness of Head, Blurred Vision, Dizzy (Eyes Open), Dizzy (Eyes Closed), Vertigo, Stomach Awareness, and Burping.

2.5. Experimental tasks and procedure

This research was conducted over three weeks. Throughout that period, each group (VR50 or TR) was active for three days, with a week of inactivity in between each active phase to prevent any interaction between the participants of the VR50 and TR groups. Figure 2 illustrates the comprehensive experimental procedure.

During the first two training days, the RN started each day with lectures on peri-care skills, followed by mannequin demonstrations. The TR group and VR50 group followed the same procedure. However, the VR50 group received a VR headset and safety instructions on the first day.

As each day's planned lectures concluded, the participants began their training. The RN examined the participants throughout their practical training; if they passed, they would advance to the skills evaluation. If the allotted time had been used, participants were required to finish their training regardless of whether they had been passed by the RN and advanced to the skills evaluation. On the third day of the research, the participants were given a practical examination on female or male mannequins, which an RN evaluated.

The VR-integrated training (VR50 group) was subjected to the experiment in the same essential way as the TR group. Both groups received the same amount of training time to complete peri-care. During the VR training, the VRNA system served as the instructor by showing step-by-step instructions to the user on an in-environment screen. This enabled the person to maximise their experience. The VRNA system will only let the participant progress to the next phase of the procedure if they complete the stated step. In VR, trainers conducted peri-care on a simulated patient using the VRNA. After completing the task at least once, participants might end their VR training early if their system-generated score was 70%. The participant's VR training ended when the time expired, regardless of whether they scored 70% or greater. This guideline ensured that VR training lasted as long as on-hand training.

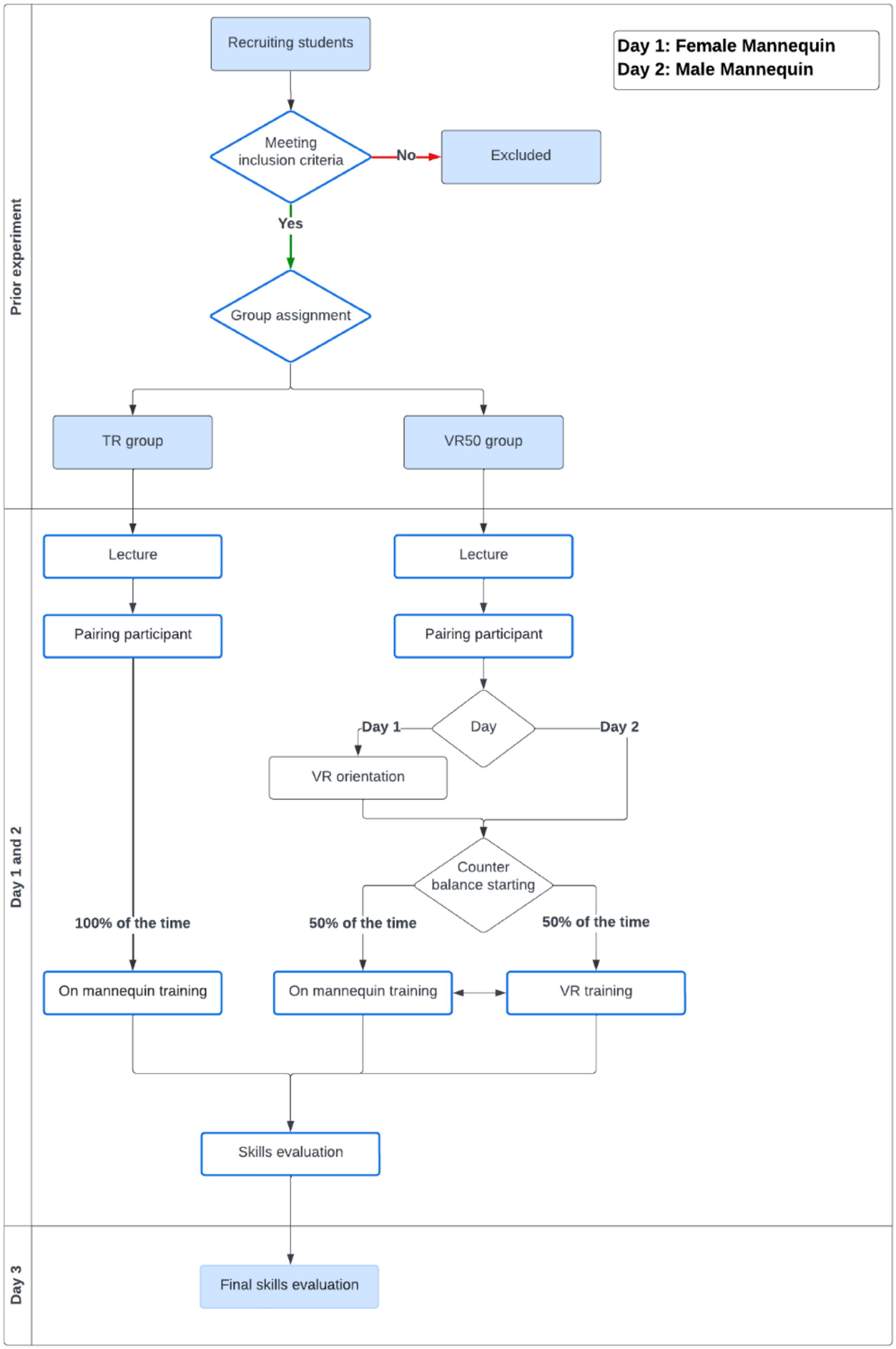

Figure 2. Experiment process.

2.6. Statistical analysis

The measures were statistically analysed using R software (ver. 2.2.0). The following packages were employed for testing, plotting, and summarising: 'tidyverse', 'devtools', 'ggpubr', and 'dplyr'.

Shapiro-Wilk test was applied to check if the variables were normally distributed. Variance equality was tested using the *F*-test. Student's *t*-test was employed when the data met the assumptions of normality and homogeneity of variance. In contrast, the unpaired two-sample Wilcoxon test was utilised when this normality assumption was not satisfied. In addition, frequency analysis and crosstabulations were employed to assess demographic and participant data. A *p*-value of <0.05 was considered a statistically significant difference among groups.

3. Results

3.1. Demographic characteristics of participants

Sixteen graduate and undergraduate participants (13 males and three females) participated in this study. All participants were in excellent physical condition. Each participant was expected to complete two training days and one testing day on three consecutive days. The TR group had an average age of 27.63 (*SD*=4.27) years, height of 167.83 (*SD*=11.85) cm, and weight of 72.65 (*SD*=14.12) kg. The VR50 group had an average age of 27.75 years (*SD*=4.83), an average height of 172.63 cm (*SD*=12.12), and an average weight of 86.49 kg (*SD*=33.31).

3.2. Performance

Table 2 shows five instruments assessed performance on each of the three days. Skills were assessed on the first and second days. The participants were examined on a female mannequin on the first day and a male mannequin on the second. There was no statistically significant difference in the skills evaluation on the first day (*p*-value = 0.528), with a higher score for the TR group and a statistically significant difference on the second day (*p*-value = 0.043), recording a higher score for the VR50 group. The final findings for the skills assessment on the third day were higher for the VR50 group (mean of 89.29) than for the TR group (mean of 86.16), but the difference was not statistically significant (*p*-value = 0.427).

The review quiz results demonstrated no statistically significant difference between the TR group and the VR50 group on the review quiz (*p*-value = 0.837), with average scores of 80.23 and 79.94 for both groups. According to the findings of the final exam, the mean performance gap between the VR50 and the TR groups was 8.34, indicating that the VR50 group had a much superior result in the final exam with a near statistically significant difference (*p*-value = 0.070).

3.3. Team learning

Of the 20 questions asked of a participant regarding team learning, only two significantly differed between groups. All of the questions found to be significantly different indicated an advantage to the VR50 group. The question 'Mistakes are openly discussed to learn from them' (TR *M*=1.750, *SD*=0.707: VR50 *M*=4.625, *SD*=0.517: *p*=0.035) indicated that participants in the VR group felt they could discuss mistakes more freely with their team members. The question 'We question each other when we think the work can be done better' (TR *M*=2.125, *SD*=0.991: VR50 *M*=4.875, *SD*=0.353: *p*=0.044) indicated that participants in the VR group were more likely to create conversation as it related to improvement for tasks than did participant in the traditional group.

3.4. Training time

The total time each participant spent to finish their training for the peri-care task was averaged for both the TR and VR50 groups. The average amount of time spent on the task is shown in Figure 3 for both training types.

Analysis revealed that the TR group had significantly shorter times than the VR50 group (*p*-value = 0.0002). The average total training time significantly decreased on the second day, as shown in Figure 4 for the TR group (*p*-value = 0.024) and the VR50 group (*p*-value = 0.038).

3.5. Cognitive development

The four domains of knowledge, comprehension, application, and analysis were used to evaluate a participant's cognitive development. Each of these domains represents a distinct aspect of cognitive capability. The mean scores for each of the four areas of cognitive development for both groups are shown in Figure 5 to determine whether there were substantial differences between the experimental groups regarding cognitive development. According to the

Table 2. Mean scores and *SD* of all performance evaluations.

	Evaluation type				
	Day 1 skill evaluation	Day 2 skill evaluation	Final skill evaluation	Review quiz	Final exam
Group			Mean ± *SD*		
TR	86.16 ± 9.63	85.71 ± 11.13	86.16 ± 9.04	80.23 ± 5.70	81.94 ± 5.75
VR50	83.04 ± 9.69	**95.54 ± 2.53**[a]	89.29 ± 4.27	79.94 ± 9.78	90.28 ± 9.27

[a]Statistically significant

findings of our investigation, there are three significant occurrences within the scores of Crooks' taxonomy. The cognitive development areas with significantly higher VR50 scores include knowledge, application, and analysis, as shown in Table 3. Also, the comprehension score is higher for the VR50 group but not significantly.

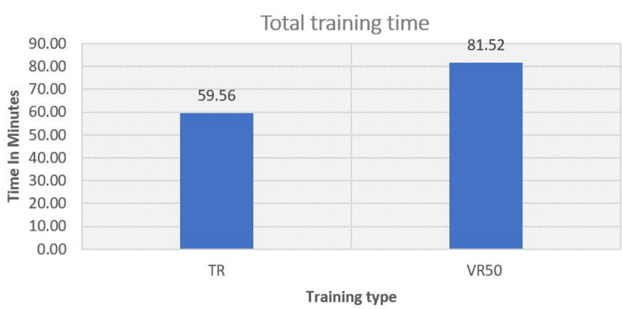

Figure 3. Average total training time for both days.

3.6. Physical development

The level of physical development was evaluated based on the average muscular activity, which was calculated as a percentage of the maximum voluntary contraction (MVC) for each of the five muscles of interest (deltoid, upper trapezius, extensor digitorum, flexor carpi ulnaris, and erector spinae) (Figure 6). A multivariate analysis of variance (MANOVA) was used to account for the multiple dependent variables (five muscles). MANOVA was used to identify any effect of the training types (TR, VR50) on muscle activities.

The findings indicated no statistically significant difference in the physical development of various muscles between the TR and VR50 groups (p-value = 0.642).

3.7. Mental workload

Compared to the VR50 group, the TR group had a descriptively lower mean MWL rating; nonetheless, there was no significant difference between the two

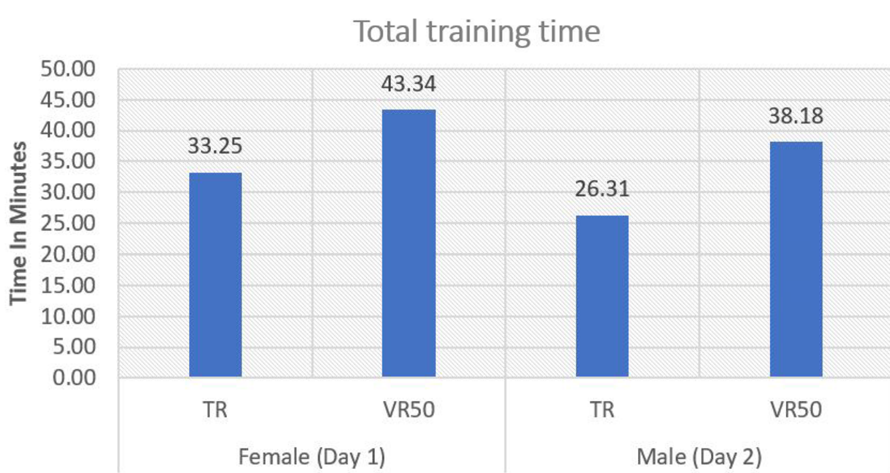

Figure 4. Average total training time on day 1 and day 2.

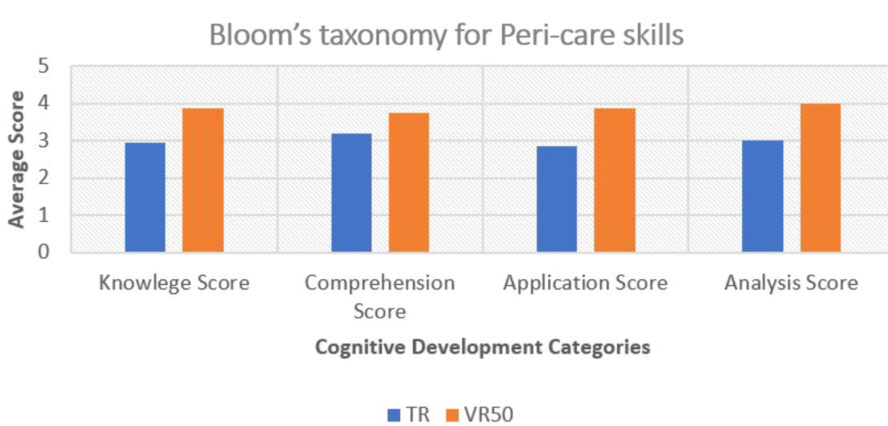

Figure 5. Cognitive scores for the TR and VR50 groups.

groups (Figure 7). The MWL ratings were not significantly different from each other.

3.8. User experience

The VR50 training's UX is satisfactory overall, with perspicuity and attractiveness obtaining the highest evaluations of 2.96 and 2.58, respectively, as shown in Figure 8. Perspicuity indicates that the product is easy to learn. Attractiveness refers to product impression. All TR UX components had scores below 2, with dependability scoring the highest and novelty the lowest. The VR50 group rated the perspicuity (*p*-value = 0.037) and novelty (*p*-value = 0.034) higher than the TR group. Novelty shows that the product is creative and attracts people. VR50 was almost significant for attractiveness (*p*-value = 0.059). Also, there is a near significant stimulation for the VR50 group (*p*-value = 0.075).

Table 3. Crooks's consideration of Bloom's taxonomy means, *SD*, and *p*-values.

Test question type	TR mean	VR50 mean	TR *SD*	VR50 *SD*	*p*-Value
Knowledge	2.94	3.88	0.86	0.35	**0.008**[a]
Comprehension	3.19	3.75	0.75	0.46	0.081
Application	2.88	3.88	0.99	0.35	**0.015**[a]
Analysis	3	4	0.96	0	**0.022**[a]

[a]Statistically significant

3.9. Students' satisfaction and self-confidence

According to the results in Table 4, the participants' satisfaction levels with VR were average (mean ± *SD*, 4.725 ± 0.06 out of 5.0). According to the study, students who participated in VR-based learning had a slightly higher level of self-confidence than those who participated in TR-based learning (mean ± *SD*, 4.41 ± 0.26 out of 5.0). However, there is not a significant difference between the two.

On each of the five measures, the participants' satisfaction in the VR50 group was greater than that of

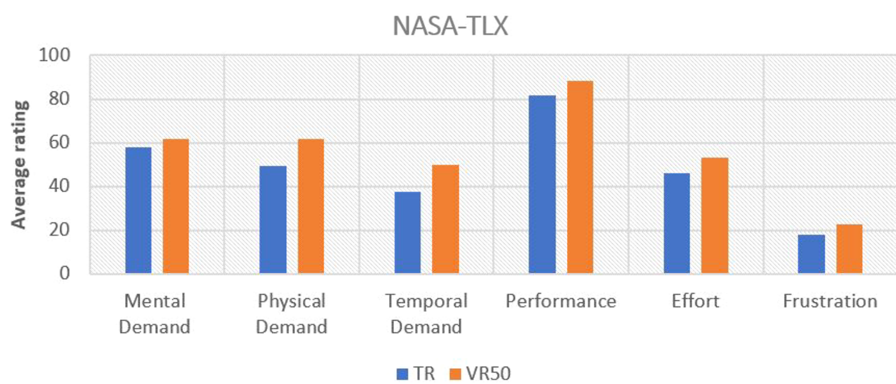

Figure 6. Average rating of NASA TLX on six dimensions.

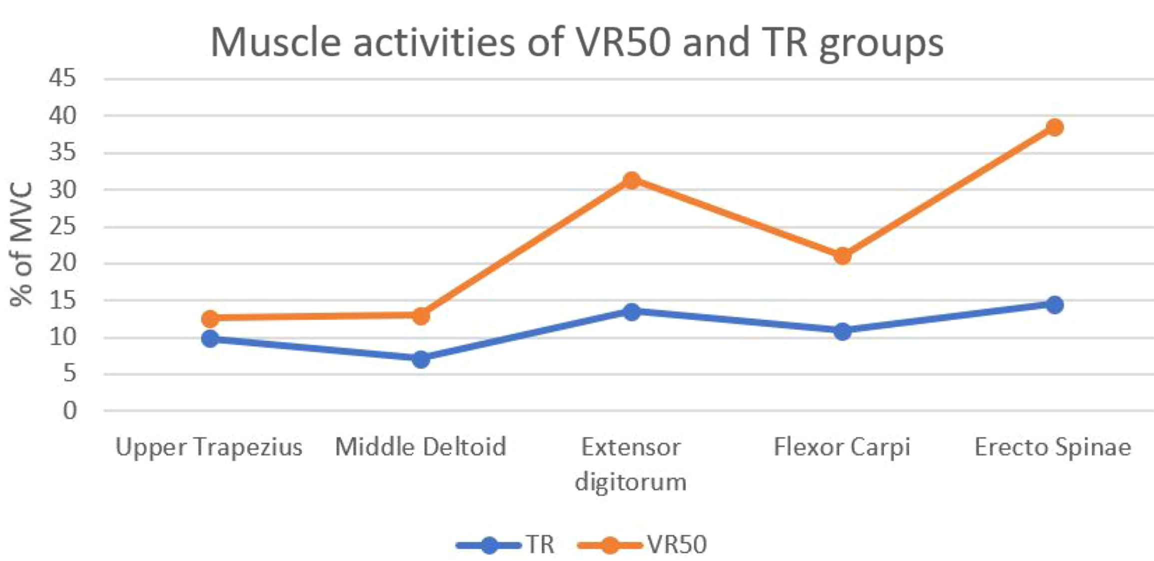

Figure 7. Muscle activities for TR and VR50 groups.

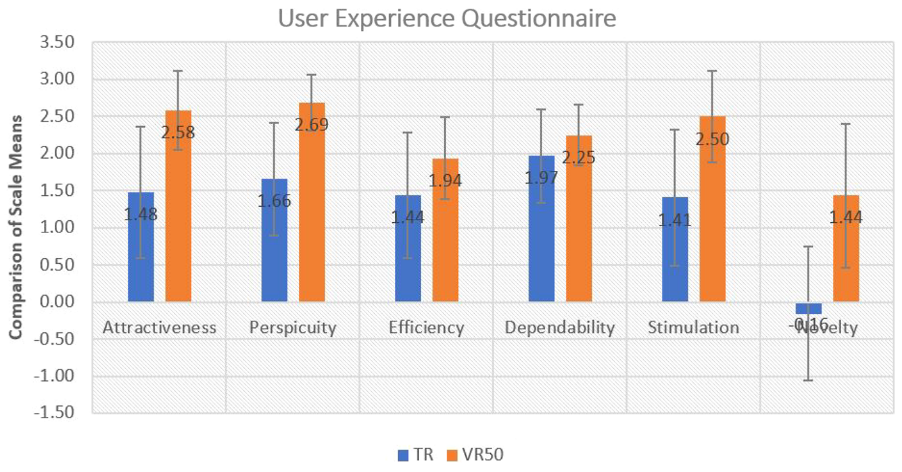

Figure 8. Average rating of UE for TR and VR50 groups.

the TR group. Participants in both TR and VR50 groups felt the least confidence related to the 'It is the instructor's responsibility to tell me what I need to learn of the simulation activity content during class time' with (mean ± *SD*, 3.75 ± 1.04 out of 5), (mean ± *SD*, 4 ± 0.76 out of 5) respectively. The participants in the VR50 group reported the highest levels of self-confidence regarding their understanding of the material, the simulation's coverage of critical material, the participant's ability to develop required skills, and the instructor's utilisation of helpful resources cited as reasons. On the other hand, participants in the TR group indicated the greatest degree of self-confidence in their capability to make use of the simulation to master critical characteristics of the skills.

3.10. Simulator Sickness Questionnaire

It has been hypothesised, based on a large sample of SSQ data collected from military pilots, that total scores can be associated with negligible (<5), minimal (5–10), significant (10–15), and concerning (15–20) symptoms. Table 5 outlines the SSQ's scoring processes. As seen in Figure 9, there is a negligible to minimum presence of any symptoms on the first day. Compared to the first day, the symptoms brought on by using the headset were more pronounced on the second day. It is claimed that the symptoms of nausea and oculomotor are minimal. On the other hand, both the disorientation and the overall symptoms are within the range of being significant.

4. Discussion

The main issues addressed in this study were (1) evaluation of the effect of VR-integrated training on the performance and training time compared to the traditional training, (2) comparison and evaluation of the cognitive and physical development by the TR group and VR50 group and (3) evaluate the MWL, UX, and students' satisfaction and self-confidence among the TR and VR50 groups.

Results of this study showed that the overall performance is similar between the two training groups, with some performance aspects superior to the VR50 group. These results were consistent with those of earlier VR research (Ma et al. 2024; Magi et al. 2023). During the second day of the skills evaluation and the final written test, it was discovered that significantly better performance had been achieved by the VR50 group, demonstrating that training using VR had either a positive effect or was just as successful as training with traditional methods.

The findings of this research indicated that using VR-integrated training would not reduce the time students spent participating in training compared to traditional training. The training times were significantly lower for the TR group. These time-based results go against the trend of past studies on VR training (Ganai et al. 2007; Jordan et al. 2000; Lapointe and Robert 2000; Stone, Watts, and Zhong 2011; Stone et al. 2011). The VR50 group still needs to acquire task skills. The increase in training time of the VR50 group is likely attributable to the fact that there are more interactions between the partners in each group, as proved by significant findings in the team learning analysis. The VR50 group felt more comfortable discussing mistakes with their team members, which counted as time. Also, the VR50 group found to discuss how to improve the task or which task can be done better, which also counted as time during the training.

Additionally, video analysis showed that the VR50 group repeatedly practiced task steps more than one time while discussing their actions with their partner.

Table 4. Participants' satisfaction and confidence of participants for TR and VR50 groups.

	TR	VR50
	Mean ± *SD*	
Satisfaction with current learning	4.4 ± 0.06	4.725 ± 0.06
1. The teaching methods used in this simulation were helpful and effective.	4.375 ± 0.74	4.75 ± 0.46
2. The simulation provided me with a variety of learning materials and activities to promote my learning of the medical surgical curriculum	4.375 ± 1.06	4.75 ± 0.46
3. I enjoyed how my instructor taught the simulation.	4.375 ± 0.74	4.75 ± 0.46
4. The teaching materials used in this simulation were motivating and helped me to learn.	4.375 ± 0.74	4.625 ± 0.74
5. The way my instructor(s) taught the simulation was suitable to the way I learn.	4.5 ± 0.76	4.75 ± 0.46
Self-confidence in learning	4.31 ± 0.27	4.41 ± 0.26
6. I am confident that I am mastering the content of the simulation activity that my instructors presented to me.	4.5 ± 1.07	4.625 ± 0.52
7. I am confident that this simulation covered critical content necessary for the mastery of medical surgical curriculum.	4.25 ± 1.04	4.625 ± 0.74
8. I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform necessary tasks in a clinical setting	4.25 ± 1.04	4.625 ± 0.52
9. My instructors used helpful resources to teach the simulation.	4.5 ± 1.07	4.625 ± 0.52
10. It is my responsibility as the student to learn what I need to know from this simulation activity.	4.25 ± 0.71	4.125 ± 1.13
11. know how to get help when I do not understand the concepts covered in the simulation.	4.375 ± 0.92	4.375 ± 1.06
12. I know how to use simulation activities to learn critical aspects of these skills.	4.625 ± 0.74	4.25 ± 1.04
13. It is the instructor's responsibility to tell me what I need to learn about the simulation activity content during class time.	3.75 ± 1.04	4 ± 0.76

Table 5. SSQ score calculations as described in Kennedy et al.

		Weight		
	SSQ symptoms	N	O	D
1	General discomfort	1	1	
2	Fatigue		1	
3	Headache		1	
4	Eye strain		1	
5	Difficulty focusing		1	1
6	Increased salivation	1		
7	Sweating	1		
8	Nausea	1		1
9	Difficulty concentrating	1	1	
10	Fullness of head			1
11	Blurred vision		1	1
12	Dizzy (eyes open)			1
13	Dizzy (eyes closed)			1
14	Vertigo			1
15	Stomach awareness	1		
16	Burping	1		
	Total	[1]	[2]	[3]

$N = [1] \times 9.54$.
$O = [2] \times 7.58$.
$D = [3] \times 13.92$.
$TS = ([1] + [2] + [3]) \times 3.74$.

The TR group, however, did not commonly repeat tasks and were less likely to discuss individual procedural steps with their partners. Furthermore, the TR group did not interact with the mannequin as if it were a real person; instead, they treated it more like a tool, while the VR50 group imitated the actual world by engaging and conversing with the mannequin.

Regarding cognitive development, three cognitive development areas statistically significantly favoured the VR50 group, with one area left favouring the VR50 group but not statistically significant. The cognitive evaluation showed that the VR50 group had significantly higher knowledge, application, and analysis development. Knowledge reflects 'involves the recall of specifics and universals, the recall of methods and processes, or the recall of a pattern, structure, or setting'. Application means 'use of abstractions in particular and concrete situations', The analysis indicates the 'breakdown of a communication into its constituent elements or parts such that the relative hierarchy of ideas is made clear and/or the relations between ideas expressed are made explicit'.

The findings of this research suggested no statistically significant difference between the TR group and the VR50 group regarding their physical development. Provided that there are defined processes to take and precise ways to do the tasks, this conclusion was straightforward and logical, given that there are no distinguishing ways to execute the jobs. This is a promising finding indicating that VR-integrated training will not negatively affect the learning of the steps. In contrast, it gave the same results as traditional training.

The study's findings indicated no difference between the individuals in the TR group and those in the VR50 group regarding the MWL that was developed coincided with (Ma et al. 2024).

Compared to the TR group, the participants in the VR50 group gave their experience considerably better ratings across the board, with the most notable increases coming in the categories of novelty and perspicuity. In addition, the participant interviews on the last day revealed that the VR group had a more positive impression of the concept and the implementation of integrated training than those in the TR

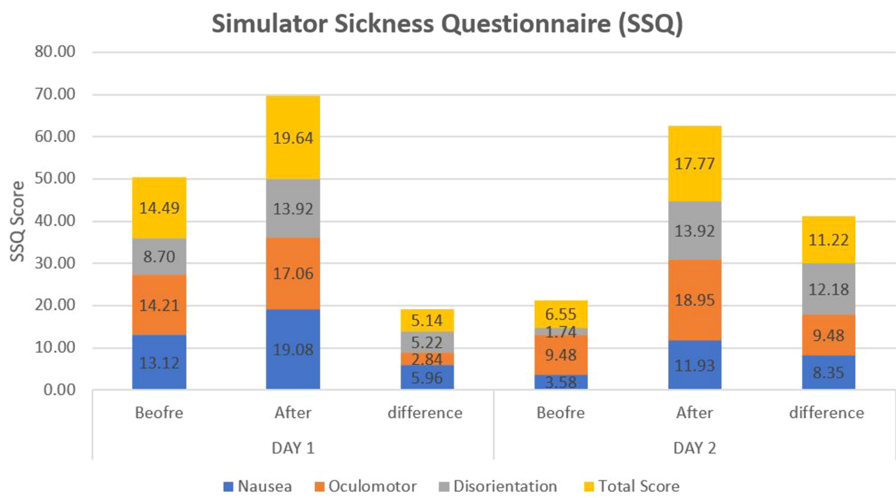

Figure 9. Simulator Sickness Questionnaire scores by days.

group. This finding aligns with previous research on students' perceptions of VR technology (Chang and Lai 2021; Ma et al. 2024; Padilha et al. 2018; Saab et al. 2021).

Another measure of the promising prospects of VR-integrated training is the degree of student satisfaction and self-confidence. The findings show no significant variance in the two groups' ratings, with the VR50 group exhibiting good tendencies.

In general, the VR headset had no statistically significant effect on the participants regarding the simulator sickness, which indicated a good interface of the VR environment as opposed to the findings by Ma et al. (2024). It can be shown that the simulator sickness decreased on day 2 compared to day 1.

5. Conclusion

In light of the overall shortage of healthcare professionals, particularly nurses, there is a pressing need to identify an efficient approach that may expedite the training of skilled and capable nurses while considering factors such as time, cost, and quality. To this end, this study evaluated the use of VR technology vs traditional training. More specifically, this work utilises a within-study approach to examine the effectiveness and efficacy of VR training technology in hands-on medical training. Performance, cognitive development, physical development, MWL, UE, Students' Satisfaction and Self-Confidence, training time, and team learning were assessed. Compared to the traditional training methods, this research has demonstrated that training incorporating VR leads to more significant cognitive development.

Additionally, the VR-integrated training demonstrated a superior experience for the VR50 group compared to the TR group. This study provides evidence that traditional training CNAs be replaced with VR-integrated training to achieve performance outcomes comparable to, and in some cases even superior to, those achieved through traditional training. The lack of identifiable distinctions in the physical development, MWL, and subjective levels of satisfaction and self-confidence among students suggests the potential efficacy of VR-integrated training as a promising approach for peri-care training.

The primary benefits of incorporating virtual VR into training encompass the empowerment of instructors, heightened learning effectiveness, promoting equitable learning opportunities, and reducing program costs. The overarching objective is to enhance the effectiveness and cost-efficiency of teaching CNA job skills, traditionally conducted in a laboratory setting. The contribution of this paper is (1) a validated immersive VR technology to train peri-care skills for CNAs and (2) a promising result to extend the testing and application of VRNA for other CNA skills.

6. Limitations and future work

To the best of the authors' knowledge, this is the first study that examined the effect of VR hybrid training and quantified the effectiveness of VR hybrid training over traditional training methods. Nevertheless, it is important to recognise several limitations.

Each group consisted of eight participants, with a total of 16 participants for the overall study. This decision was based on technology-related resources expert training staff, and a significant time commitment from the participants themselves. Ultimately, eight participants were the maximum manageable to guarantee real-world levels of student-to-trainer support and ensure that all applicable materials were available and in full operational order for the participants.

Participants in VR50 were given a fixed amount of time to explore and get used to the VR environment and controller so as not to impact the overall experimental training time. Extending the orientation time to the VR environment and controllers should be considered in future studies when the participants do not have previous experience in VR.

The instruction and training spanned two consecutive days, followed by testing on the third day. It posed a challenge to arrange for participants to return for additional testing after one week, two weeks, or even six months to assess skills retention between the VR50 and TR groups. Therefore, it is intriguing to examine the efficacy of the VR50 training method in retaining skills after a period of time.

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