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Comparison of Knowledge Retention after the Use of a Virtual Patient versus a High-Fidelity Physical Simulator and Traditional Training

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Abstract

Aim: This research assesses the effect of a virtual patient simulation platform CyberPatient (CP) compared to a high-fidelity physical simulator SimJunior (SJ) and traditional bedside training (TBT) on knowledge retention and competencies in a health education environment. **Material:** A total of 143 fifth-year medical students were randomly assigned to three groups: TBT-Group (n = 55) received traditional education; CP-Group (n = 44) was trained with a virtual patient platform CyberPatient; and SJ-Group (n = 44) was trained using a high-fidelity simulator SimJunior. Educational content for all groups included competencies on pediatric asthma. **Methods:** Students' level of knowledge acquisition was measured with a multiple-choice question test (MCQ) administered before the application of educational methods (Assessment I), immediately after completion of pediatric asthma training (Assessment II), and knowledge retention was measured two months later the completion of training (Assessment III). At the end of the study, student satisfaction was also measured by a survey questionnaire containing 5 questions rated on a Likert scale. **Results:** Assessment of acquired knowledge immediately after completion of pediatric asthma training revealed a significant difference between TBT-Group and SJ-Group ($p < 0.05$) only. However, the knowledge retention score was significantly ($p < 0.05$) higher for the CP-Group (91.89 ± 17.67) and SJ-Group (90.14 ± 19.48) in comparison to TBT-Group with traditional education (82.63 ± 26.22). **Conclusions:** Virtual training with CyberPatient and high-fidelity physical simulation had a significant ($p < 0.05$) positive impact on memory retention compared to traditional clinical teaching. The possible mechanisms behind this positive impact include hands-on, active engagement, multi-sensory experience, spaced repetition, transfer of learning, and motivation. The inclusion of virtual simulation in the medical curriculum can improve the training of clinical competencies.

Keywords

Medical Education, Knowledge Retention, Virtual Patient, CyberPatient, SimJunior

1. Introduction

Memory works through the interaction of our unconscious (routine) and conscious (problem-based) thought processes (Derek Bok Center, n.d.). In an educational context, our unconscious processes are related to memorization and recall (e.g., remembering textbook knowledge for a multiple-choice test) (Derek Bok Center, n.d.). In contrast, our conscious processes relate to analytical thinking (e.g., solving a case study) (Derek Bok Center, n.d.). But analytical thinking often depends on memory and recall (Derek Bok Center, n.d.). Stages of memory are encoding (method of learning), storage (long-term vs. short-term memory), and retrieval (accessing memory) (Derek Bok Center, n.d.; McCrudden & McNamara, 2017). Different methods of learning and practicing to access memory can help with memory retention. For example, frequent testing of knowledge, introducing content over time or practicing related skills/topics simultaneously to the topic at hand help increase memory retention in education (Derek Bok Center, n.d.).

Long-term memory can be procedural (skill) or declarative (facts) (Ten Berge & Van Hezewijk, 1999). It is common to lose one-third of gained knowledge after one year without using (Custers, 2010). Retaining learned memory in medical education is vital to apply such in practice. Simulations can help retain knowledge for longer periods of time. For example, pilots use flight simulators, and surgeons use surgical simulations as a knowledge refresher (Sears, 2020). A meta-analysis reviewing study (n = 39) that compared simulation-based education to non-simulation-based learning showed an increase of 9% in memory retention with simulations (Sitzmann, 2011).

Virtual simulations have increased benefits for memory retention compared to physical simulations. Virtual simulation games used in health care are said to be effective when including the following components: range of difficulty, repetitive practice, distributed practice, cognitive interactivity, multiple learning strategies, individualized learning, mastery learning, feedback, longer time, and clinical variation (Cook et al., 2013).

We hypothesized that memory retention using virtual simulation platforms is higher than physical simulation and/or traditional bedside teaching.

The objective was to assess the effect of a virtual patient simulation platform CyberPatient (CP) in comparison to a high-fidelity physical simulator SimJunior (SJ) and traditional bedside training (TBT) on knowledge retention for clinical competencies.

We anticipated that integrating virtual simulation platforms such as Cyberpatient would open a new diminution in training clinical competencies and other curricular activities in health education.

2. Research Questions

Do virtual patients provide better knowledge retention for students to gain clinical competencies in a clerkship rotation?

3. Methods

Participants

At Plovdiv Medical University (Bulgaria), 5th-year medical students in pediatric clerkship rotation were invited to participate in the study. 143 students voluntarily signed up and participated in this study.

The study was conducted in the Department of Pediatrics of University Hospital St. George for the traditional method, in the Medical Simulation Training Center of the Medical University of Plovdiv for SimJunior, and a subscription for CyberPatient allowed them to study from anywhere, including from home.

Study Design

The experimental design included a prospective randomized trial where judges were nested and blinded to the experimental groups. Students were subjected to three separate assessments. Assessment-1 served as a pre-test and was conducted before the start of the rotation. Assessment-2 was conducted immediately after the completion of training, and Assessment-3 was conducted two months after the completion of the training. In addition, students had their routine examinations as part of the university curriculum. The experiment was divided into the following three phases:

1) Preparation Phase
2) Experimentation Phases
3) Knowledge Retention Phases

3.1. Preparation Phase

In this phase, volunteer Students were invited to attend an orientation session, where they completed the demographic data sheet and were subjected to Assessment-1 (pre-test) to establish the baseline. This assessment (Pre-test) was also used as a control value for each student and each group. Students also attended a lecture on childhood bronchial asthma to standardize the input information. The lecture on bronchial asthma is part of the pediatric rotation program. The lecture was online due to the restrictions related to the pandemic. The educational content for acquiring knowledge and competencies was the same in all three groups and included clinical decision-making on pediatric asthma. Participants (N = 143) were randomly assigned to the following three groups:

1) TBT-Group (N = 55) was subjected to traditional bedside teaching (this group was used as the control)

2) CP-Group (N = 44) was trained with a virtual patient (CyberPatient)

3) SJ-Group (N = 44) was trained using a high-fidelity simulator (SimJunior)

3.2. Experimentation Phases

Before experimentation, students in each group were subjected to a training session for the useability of technology to exclude the methods' effect on acquiring knowledge and competencies.

In TBT-Group, students were trained on two actual pediatric asthma patients. The training included history taking, physical examination, differential diagnosis of a child with the broncho-obstructive syndrome, therapy and follow-up. The following key points were discussed during the training: diagnosis, differential diagnosis, necessary laboratory tests for diagnosis of bronchial asthma, therapy of children with asthma attacks and indications for hospitalization. The duration of the discussion was 90 minutes.

CP-Group participants were trained using two virtual patients with childhood asthma on the CyberPatient platform. Before the initiation of this experiment, the CP-Group students were trained to become familiar with the UI/UX of the CyberPatient platform. After familiarization with the platform, each student was given access to two clinical pediatric asthma cases for seven days as a self-directed study tool. During the study time, students could complete the case as often as they wanted. After the training, a debriefing seminar was held with the students to discuss the same criteria as in TBT-Group for diagnosis, differential diagnosis, laboratory tests required for the diagnosis of bronchial asthma, therapy for children with an asthma attack, criteria for hospitalization, and management of asthma attacks. The duration of the discussion was 90 minutes.

Students in the SJ-Group were trained in the simulation center using high-fidelity physical simulators SimJunior. Two branched clinical scenarios developed by the research team and integrated into the high-fidelity simulators were given to students to practice. The training included history taking, physical examination, differential diagnosis of a child with broncho-obstructive syndrome therapy and follow-up. After the simulation, a debriefing session was held to discuss the criteria for diagnosis, differential diagnosis, laboratory tests required to diagnose bronchial asthma therapy and hospitalization for children with an asthma attack. The duration and content of this debriefing seminar were the same as CP and TBT-Groups (90 minutes).

At the end of the experimental phase, immediately after the completion of training, Assessment-2 was performed to establish the effect of the teaching methods on the acquisition of knowledge and competencies.

3.3. Knowledge Retention Phases

This phase was completed two months after the experimental phase (February 2022). In this phase, students were subjected to Assessment-3, which included similar multiple-choice questions (MCQ) to assess knowledge retention in all three groups.

Data Collection and Data Analysis:

This prospective study was conducted on 143 medical students in the 5th year of their study at the Medical University of Plovdiv. The knowledge and clinical competencies acquired through three teaching methods were analyzed. The logical units of observation were the 5th-year Medicine students. The main observation points were the acquired knowledge and clinical competencies, their retention in the studied groups, and learning satisfaction. The clinical scenario entitled "Bronchial asthma in childhood" was used for all groups.

The knowledge acquisition and retention instrument consisted of 26 multiple-choice questions related to pediatric bronchial asthma. The MCQ content was covered by a lecture presented to all groups, and the textbook in Pediatrics by Lissauer and Carroll (2021) was available for all students. In addition, all students received ten clinical cases of bronchial asthma to exercise their knowledge and competencies. Examiners were blinded to the groups of students.

The MCQ instrument was used for all three assessments. The first time it was used as a pre-test; the second time to assess the effect of educational methodologies; and the time to assess the ability of the students to retain knowledge.

Learning satisfaction among students was measured by a questionnaire containing five questions rated on a Likert scale. The research team developed this satisfaction survey questionnaire, and it was not validated. This survey was conducted at the end of the study only (February 2022).

Students were given a unique ID, and data from these assessments were entered into a database by an independent researcher who was also blinded.

Descriptive statistics, including mean and standard deviation, were used to check the normality of the data before applying statistical methods for comparative analysis.

For hypothesis testing, Parametric methods such as T-test and non-parametric methods such as Kolmogorov-Smirnov and Shapiro-Wilk, Mann-Whitney, and Kruskal-Wallis methods were used. Other statistical methods included the Chi-square test or Fisher's exact test, Median test, Correlations, and Linear regression analysis were also used.

Data were analyzed using the Statistical Package (SPSS) ver. 26.0 for Windows. Coded Data were analyzed. The level of significance used was $\alpha = 0.05$, and the corresponding null hypothesis was rejected if the p value was less than α.

4. Results

Results of demographic data show that the average age of the students was 23 years. More females (58%) than males (42%) participated in the study groups.

Results of the first assessment test (Assessment-1, Pre-test) conducted with all 143 students. The minimum passing score for students on this test was 76 points. This assessment showed lower-than-expected scores for students in all groups due to the need for more knowledge about the subject. The average test score for all students in all groups was 56.70 ± 18.10 (minimum score 14 and maximum score 92.5). The Assessment 1 test scores for the CP-Group of students trained on a virtual patient (CyberPatient) was 57.99 ± 16.63; the JS-Group trained on a high-fidelity simulator scored 56.18 ± 19.50; and the TBT-Group that performed traditional training had a score of 56.07 ± 18.35. There was no significant difference between the groups in this pre-test (Figure 1 and Table 1).

Results of Assessment-2, which was performed after the completion of the experimental phase, showed a higher score for all groups. However, this difference was significant ($p < 0.05$) for JS-Group (97.31 ± 20.66), where students trained on a high-fidelity simulator, in comparison to TBT-Group, where

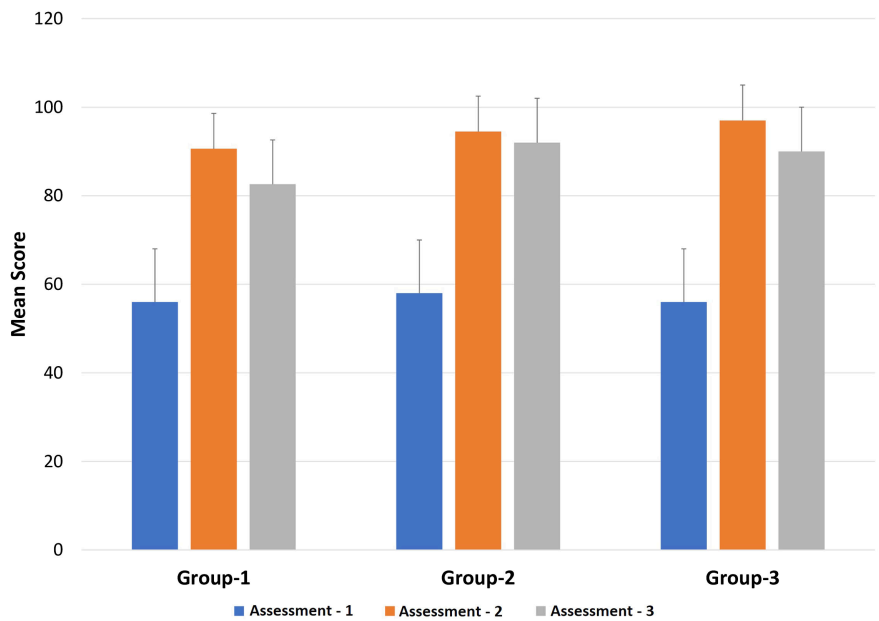

Figure 1. Depicts student performance for each group before and after the three interventions. It clearly demonstrates the superiority of simulation over the traditional method of teaching clinical competencies.

Table 1. Assessment score, standard deviation, and degree of significance (P) for all groups.

Groups	Mean Score ± SD		
	Assessment-1	Assessment-2	Assessment-3
TBT-Group	54.88 ± 18.26	90.58 ± 25.11	81.76 ± 25.8
CP-Group	58.01 ± 16.61	94.51 ± 19.39	91.89 ± 17.67
SJ-Group	55.73 ± 19.51	97.31 ± 20.66	90.14 ± 19.48
p value between groups	NS	<0.05	<0.05

traditional training was used. The assessment score for CP-Group trained on a virtual patient was 94.51 ± 19.39, which was higher than the TBT-Group but did not reach significance. The results of the TBT-Group were 90.58 ± 25.11, which was the lowest of all three groups (Figure 1 and Table 1).

Regression analysis of Assessment-1 and Assessment-2 for all groups of students showed a significant ($p < 0.0001$, and F = 0.0002) increase for Assessment-2 in relation to Assessment-1 (Multiple R = 0.52, $R^2 = 0.27$). The average score of all students increased by more than 1.6 times from 56.70 in Assessment-1 to 93.86 in Assessment-2 (Figure 2).

Results of Assessment-3, which was administered two months after Assessment-2 for knowledge retention, demonstrated a minimal, not significant reduction in the acquired knowledge for students in all groups compared to Assessment-2 with an average of 87.79 ± 22.01 points in Assessment-3 compared to 93.86 ± 22.16 points in Assessment-2.

However, when individual groups were compared, the knowledge retention score on Assessment 3 was significantly ($p < 0.05$) higher for CP-Group (91.89 ± 17.67) and SJ-Group (90.14 ± 19.48) in comparison to TBT-Group with traditional education (82.63 ± 26.22) (Table 1).

In Table 2, the student satisfaction survey results are displayed. 64% of students believe they have significantly increased their knowledge following the training. Among them, 90.21% reported that the training had improved their practical skills, and 88.81% reported that the discussion during and after the training was helpful. Overall satisfaction with training amounted to 91.61%. The

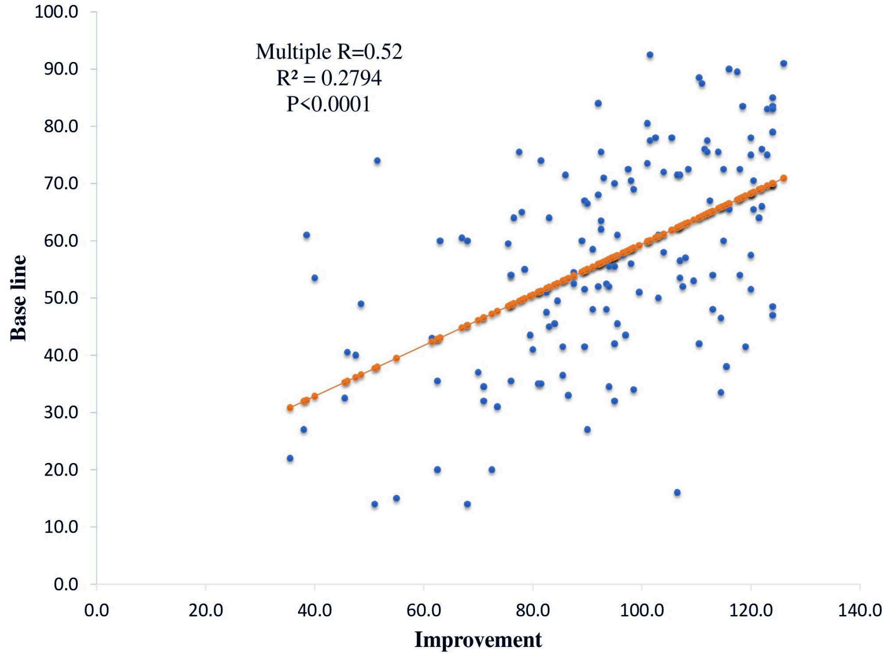

Figure 2. Linear regression of the total number of points from Assessment-1 and Assessment-2 indicates that students have significantly ($p < 0.0001$) improved in relation to the baseline.

Table 2. Student satisfaction survey results.

Question	Group	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Do you think that this training increased your practical knowledge, skills and competencies	*TBT-Group*	20/55 (36.4%)	26/55 (47.3%)	5/55 (9.1%)	4/55 (7.2%)	-
	CP-Group	23/44 (52.3%)	18/44 (40.9%)	2/44 (4.5%)	1/44 (2.3%)	-
	SJ-Group	27/44 (61.4%)	15/44 (34.1%)	-	2/44 (4.5%)	-
Are you satisfied with the training on bronchial asthma in childhood?	*TBT-Group*	26/55 (47.3%)	22/55 (40.0%)	2/55 (3.6%)	1/55 (1.8%)	4/55 (7.3%)
	CP-Group	32/44 (72.7%)	9/44 (20.5%)	-	3/44 (6.8%)	-
	SJ-Group	34/44 (77.3%)	8/44 (18.2%)	-	1/44 (2.3%)	1/44 (2.3%)
Did you find the discussion during the training useful?	*TBT-Group*	24/55 (43.6%)	21/55 (38.3%)	8/55 (14.5%)	1/55 (1.8%)	1/55 (1.8%)
	CP-Group	33/44 (75.0%)	8/44 (18.2%)	1/44 (2.3%)	2/44 (4.5%)	-
	SJ-Group	34/44 (77.3%)	7/44 (15.9%)	1/44 (2.3%)	2/44 (4.5%)	-

Question	Group	Excellent	Very good	Good	Satisfactory	Poor
How would you assess the level of your knowledge after the training regarding the differential diagnosis in a child with recurrent episodes of broncho obstruction?	*TBT-Group*	13/55 (23.6%)	12/55 (21.8%)	22/55 (40.0%)	6/55 (11%)	2/55 (3.6%)
	CP-Group	11/44 (25.0%)	19/44 (43.2%)	10/44 (22.7%)	4/44 (9.1%)	-
	SJ-Group	14/44 (31.8%)	23/44 (52.3%)	5/44 (11.4%)	2/44 (4.5%)	-
How would you assess the level of your knowledge after the training regarding the therapy in a child with asthmatic status?	*TBT-Group*	10/55 (18.2%)	19/55 (34.5%)	18/55 (32.7%)	7/55 (12.7%)	1/55 (1.8%)
	CP-Group	11/44 (25.0%)	15/44 (34.1%)	14/44 (31.8%)	4/44 (9.1%)	-
	SJ-Group	20/44 (45.5%)	16/44 (36.4%)	6/44 (13.6%)	2/44 (4.5%)	-

students learning through a high-fidelity simulator have the highest satisfaction score, followed by virtual patient learners. The group with the lowest satisfaction was the traditional form of learning.

5. Discussion

In this study, we hypothesize that memory retention in gaining clinical competency is more significant when using virtual simulation platforms and high-fidelity physical simulation than traditional teaching methods. This study evaluated and compared the effect of these three methods in a pediatric clerkship clinical program. The results of this study rejected the null hypothesis. However, they confirmed that knowledge retention after two months was significantly ($p < 0.05$) higher in the virtual simulation, where CyberPatient was used and in high-fidelity physical simulation, compared to traditional training. This finding is novel and has not previously been proven in a clinical learning environment. Results of this study also show that both types of simulation, physical and virtual simulation, have a significant ($p < 0.05$) positive effect on learning clinical knowledge and competencies compared to traditional methods immediately after the course completion. The impact of simulation in relation to conventional learning methods in medicine and aviation has already been proven and discussed by others (Merrill et al., 2015; Patel et al., 2010; Reznick et al., 2003). Therefore, we will discuss the effect of knowledge retention through virtual simulation to understand the reasons behind this novel phenomenon in medical education.

Virtual simulations have become an increasingly popular tool for learning and training in various fields (Miller, 1956; Hamann, 2001; Petruzzello et al., 1997; Diekelmann & Born, 2010). One of the key benefits of virtual simulations, described by these authors, is their impact on memory retention. According to scientific literature, several factors can improve memory retention. These factors may include attention, concentration, repetition, association, emotional relevance, sleep, exercise, and others. However, the effect of virtual simulation on memory retention may include additional factors such as active engagement, multisensory experience, spaced repetition, transfer of learning, and motivation (Van Merriënboer, 2013; Salomon & Perkins, 1989; Roediger & Karpicke, 2006; Rizzo & Kim, 2007).

Previous research demonstrated that hands-on, active learning improves memory retention compared to passive learning (Van Merriënboer, 2013). That is why the virtual environment provides a better condition for students to learn. CyberPatient is an interactive platform that supports hands-on, active learning. The positive effect of CyberPatient as a hands-on, active learning tool compared to passive textbook learning was demonstrated in a previous study (Kurihara et al., 2004; Qayumi et al., 2004).

CyberPatient is designed to provoke multisensory experiences that include visual, auditory, and tactile memory. The effect of design on memory retention is proven in a review of virtual reality exposure therapy for anxiety disorders (Rizzo & Kim, 2007). Their research demonstrated that virtual simulation could enhance information encoding in memory, resulting in increased retention. The constant use of visual, auditory, reading, and tactile memory in CyberPatient has been integral to instructional design (Qayumi & Qayumi, 1999).

Spaced repetition is a powerful memory retention strategy (Roediger & Karpicke, 2006). By nature, CyberPatient incorporates spaced repetition. CyberPatient is an intuitive educational platform accessible to learners anytime, anywhere, allowing them to practice and repeat as often and whenever needed. The average time to complete a case is 30 minutes. The time depends on the case's complexity, the platform's gamified nature, along with pedagogical values such as learning objectives, machine assessment, and feedback to motivate students to repeat the cases. Repetition of cases in a clinical environment or using physical simulation is challenging and substantially increases the cost of medical education. In contrast, repetition within a virtual simulation environment is easy to achieve and not costly. The cost comparison of CyberPatient with standardized patients (SP) is described in a study done at the University of British Columbia (Farahmand, 2020).

CyberPatient is a virtual simulation tool designed for experiential learning and improving clinical competencies. The pedagogical theory behind CyberPatient is the transfer of learning and, more specifically, cognitive transfer. Since the transfer of learning describes how our prior experience affects our present or future experiences, the virtual simulation will be ideal for receiving the first experience in a non-penalized environment. The accepted theory behind the mechanism of transfer of learning is the formation of a semantic neuronal network in the long-term memory representing the primary experience that can be recalled with a second similar experience (theory of recall recognition memory) (The Human Memory, 2022). Therefore, the simulation of medical competencies in a virtual environment can help form an initial semantic neuronal network that can prompt recall-recognition memory in a real-life situation. This opinion is shared by others (Salomon & Perkins, 1989). These authors believe that virtual simulation helps transfer learning from the virtual environment to real-world situations, thus increasing the likelihood of long-term memory retention. The authors also emphasize the need for further research to improve our understanding of transfer and to develop novel effective strategies for promoting transfer in educational settings. The transfer of learning theory behind CyberPatient supports this study's outcome on improving knowledge retention (Farahmand, 2020).

Motivation is another factor that can contribute to memory retention in a virtual environment. Van Merriënboer (2013) believes that virtual simulations can be designed to be engaging and motivating, increasing attention and effort invested in learning and resulting in improved memory retention. Interactivity also allows the brain to engage with the virtual world constantly. Therefore, the more interactive the platform is, the more engaging and motivating it will be. CyberPatient is an intuitive and highly interactive simulation tool, and it is also gamified to the extent of not losing the pedagogical values and can provoke engagement, motivation, and attention. A separate survey study showed that 96% of students believed the CyberPatient platform was intuitive. In addition, over

90% of students considered CyberPatient a valuable teaching tool, and 89.9% perceived the CyberPatient platform to impact their clinical performance positively (Mukharyamova et al., 2020).

Analysis of the literature on memory retention supports the finding of this study. In addition, it provides the basis for understanding the mechanisms behind improving memory retention caused by virtual simulation. The neuronal mechanisms of memory retention involve activating specific brain regions and modulating neural circuits that process and store specific experiences. Phelps (2006) believes that emotional memory retention includes activating the amygdala and sending signals to the hippocampus, which is responsible for forming long-term memory. The neuronal mechanism for hands-on, active learning memory involves the activation of brain regions responsible for motor function, planning, execution, and working memory. This includes the engagement of the motor and parietal cortex (Ranganathan & Freyd, 2006). Concerning the multi-sensory effect of virtual simulation, the sensory information from modalities, such as vision, audition, tactile, and others, can activate emotional arousing and, through the amygdala, affect the hippocampus (Noulhiane et al., 2007; LeDoux, 1994). In fact, every modality will have its impact, and the overall effect of multi-sensory virtual tools will be compounded from all sensors. The neuronal mechanism of repetition for memory retention involves strengthening connections between neurons. This strengthening of these connections is known as synaptic plasticity. It is thought to be the underlying mechanism for forming and retaining memories (Wixted, 2004). Research has shown that motivation can also influence memory by activating the brain's reward system, which is associated with releasing neurotransmitters such as dopamine (Pessoa, 2008). Activation of the brain's reward system enhances the encoding and retrieval of information, particularly in regions associated with working memory, such as the prefrontal cortex (Salimpoor et al., 2013).

In summary, increased memory retention after using virtual simulation is based on stimulating specific brain parts, including the sensory and motor cortex, subcortical elements such as the amygdala, hippocampus, and hormones such as dopamine that affect the formation of semantic neuronal networks for specific experiences. These networks can then provide the opportunity to transfer learning from a virtual to a real environment.

6. Conclusion

In conclusion, in this experiment, virtual simulation using CyberPatient and high-fidelity physical simulation positively impacted memory retention compared to traditional clinical teaching. The mechanism behind this impact of virtual simulation includes hands-on, active engagement, multi-sensory experience, spaced repetition, transfer of learning, and motivation. These advantages, in addition to accessibility, make virtual simulations valuable for learning and training in clinical medical education by providing the opportunity to form the initial semantic neuronal network for competencies and transfer of competencies from a virtual environment to a real-life situation.

Conflicts of Interest

This study was not funded by industry. The authors declare no conflict of interest except for Dr. Qayumi, who was excluded from data collection and interpretation by the research committee.

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