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Application of Virtual Reality (VR) Technology for Medical Practitioners in Type & Screen (T&S) Training

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Abstract

Nowadays, patients' safety is the top priority for medical services around the world. However, it is believed that many of the adverse events in hospitals are preventable. Type and screen (T&S) procedures require intense practical training by each medical practitioner in each hospital. This study applied an interactive Virtual Reality (VR) technology to supplement the traditional approach to facilitate procedural training, and also investigated the conceptual model for medical training. The VR system made use of the Unity3D for application development. To investigate the reliability and validity of the conceptual medical training model, a survey was conducted to measure the content, motivation, and enhanced readiness of practitioners. The partial least squares (PLS) modelling was carried out to investigate the correlation between each pair of measured variables.

The study results indicated that the learning model has good reliability for each measurement factor and validates the survey study. The PLS modelling also indicated a significant correlation between each pair of measured variables including content and motivation, as well as motivation and enhanced readiness. The project developed a VR training program for training in T&S procedures. The study provides important implications on the development of a practical VR training program for medical practitioners, as well as valuable insights for the development of similar VR training programs in the future.

Keywords: Virtual Reality, Type and Screen, Medical, Training, Procedures

Introduction

Nowadays, patients' safety is the cornerstone of high-quality medical services in Hong Kong and also around the world. It is believed that up to half of the adverse events in hospitals are preventable and many patients' accidents or death can be avoided with safe clinical practice (Kizer, 2005; Rutten, 2015) With the mission of offering high-quality medical services, medical staff and professionals are required to demonstrate a high level of skill. Therefore, practical skill training no matter whether a student in a medical degree programme at university or as an intern is very important (Jaschinski, 2008; Morris, 2016). Alongside a high level of knowledge in medical education, skill training is one of the very critical components in medical education, particularly in clinical practice, which demands a high level of tacit skills. There is a number of challenges in medical skill training design, such as the repetitive practice, the acquisition of tacit skills, and the internalization of skills.

Type and screen (T&S) is an essential protocol and diagnostic procedure for patients in order to detect any unexpected antibodies, as well as checking the blood group and type (Gupta, 2011). Type refers to phenotype typing including ABO groups and Rh types, and screen refers to the unexpected antibodies testing that might cause a delay in the crossmatching of blood and increased risk of alloimmunization or transfusion reaction (Seheult, 2017; Yazer, 2006). The T&S procedures was investigated to reduce the complexity, it is much cheaper than other protocols and provides the same level of safety (Alavi-Moghaddam, 2014).

Despite there being various approaches to identify the antibodies and testing for ABO/RH types, the blood banks in North America and Europe mainly adopt the T&S protocol. It is also widely implemented in the Hong Kong Hospital Authority (Klein, 2008). The T&S transfusion practice is believed to be safe, efficient, and beneficial to the hospitals (Devbhandari, 2013).

However, there are still many inadequate T&S procedures that have been reported. These inadequate T&S procedures may result in local contamination, insufficient blood volume being withdrawn, mistakes in handling specimens, or other reasons (HA, 2012). This not only impacts on patients' care, leading to increased patient stays in the hospital and additional tests, but also inappropriate antibiotic testing results. Therefore, T&S training for sample extraction is essential to doctors, nurses, and medical interns in all hospitals (Michael, 2014).

The pedagogical design for medical education involves not only textbook knowledge but also extensive practical skill training. Practical training, as part of clinical practice, involves a significant amount of standardized procedures, which demand students to revise and practice repetitively. Concerning the nature of procedural training, Virtual Reality (VR) is considered as an effective intervention for facilitating procedural training, for its scenario simulation features allows learners to experience unlimited use, without hassle. VR is an emerging technology for providing education and training in a simulated environment. VR offers benefits to the learners, as well as educators. Traditionally, many practical training programme require the use of many cleaning consumables including alcohol prep pads, sanitizers, gloves, specimen bottles, etc., which is very wasteful and makes the training sessions non cost-effective. T&S training is an essential practice for each medical practitioner and is usually conducted by a pathologist. Nevertheless, due to the insufficient medical labor worldwide, there is a serious shortage of trainers to conduct practical training. For instance, in Hong Kong, the trainee-trainer ratio is up to 70:1 for each session. This arrangement is not favorable for repetitive training, and many medical practitioners do not have sufficient opportunities to practice before facing patients (Pottle, 2019). On the other hand, the simulated VR training allows users to practice interactively under a simulated environment which is difficult to be found in real practical training. The simulated VR training allows the simulation of external distractions during a training, as well as dynamic interaction with the patients, such as conversations. Therefore, interactive VR training provides an entirely immersive and dynamic simulation. VR supported simulation for T&S training is not only cost-effective but also safe, repeatable, and provides standardized training on demand (Tang, 2020).

With the problem centered on procedures training in medical education, this paper presents an innovative integrated learning design for medical training, particularly for the acquisition and memorizing of essential procedures. The integrative design of the training comprises traditional learning and scenario learning with the assistance of VR. The rest of this paper presents the theoretical background and the development of the training design, as well as the evaluation of the development training framework.

Learning Approaches

Learning Content and Motivation of students

There are two main types of learning motivation including intrinsic and extrinsic motivation (Reena, 2010). Intrinsic motivation is important to motivate students to finish tasks. It is the dominate type of motivation for students and is usually perform better than the extrinsically motivated students. To increase the intrinsic motivation of a student, it can be enhanced through engaging learning experiences such as VR, games, simulation, etc. In order to attract student’s attention, the design of learning content is important (Krystle, 2012). Rich learning content allows students to gain and experiences enough information of the practice or training to real-life (Handley, 2010).

Extrinsic motivation refers to the external regulation for the medical practitioners to behave and perform in the presence of specific external contingencies (Richard, 2000). In the VR T&S training extrinsic motivation such as guidance of teachers, peer sharing, and the impact of the training programmes to the patients (Rubak, 2011).

To enhance the outcomes and effectiveness of practical training, trainee readiness is critical (Chung, 2013). The students' readiness in participating in the training is usually associated with the student's motivation (Arie, 2014). Providing immersive experiences in such VR training allows students to have deeper understandings of relevant subject matter and information. However, more researches on the relationship between the above factors for VR practical training should be investigated. Hence, in this study, content, motivation, and readiness are the three significant individual factors, to be studied in this article.

Implementation of VR in medical skill training

Simulation training has attracted significant attention in recent years, especially in the field of clinical training, for its ability to shorten the learning curve and reduce human errors. Nowadays, Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) technologies are widely used in many training programs, conferring a wide range of benefits for academia and industry (Tang, 2018). VR is considered as an effective intervention to facilitate procedural training, for its scenario simulation features allow learners to experience unlimited usage without causing additional cost. It also offers novices a realistic environment for learning.

In the recent education 3.0 revolution, defined by educational theorists in various ways for integrating technology into learning, a significant compelling of 3D content is used. The use of 3D content allows enrich information to be presented in 3D. The abstract 2D thinking can be converted to more natural 3D environment, so that learners can obtain more solid illustrations.

Despite the screen-based simulated training previously been referred to as ‘virtual reality’ in healthcare and medical training, such training is only based on a 2D screen and is non-immersive. Nevertheless, the value of VR supported simulation training comes from the immersive experience and the sense of presence through the stereoscopic effects that create a ‘real’ feeling (Radianti, 2020). The immersive and stereoscopic effects in T&S training are particularly important as T&S usually involves the use of sharp instruments such as syringes, while needle stick injury is a common hazard for many medical practitioners (Goel, 2017). The immersive VR training enables the medical practitioners to practice in their working environment in hospitals, as well as practicing without distractions. The stereoscopic content also enables trainers to practice with a sense of 3D depth to avoid the possibility of needle stick injury in performing real T&S.

Traditional training design

Traditionally, the “See one, do one, teach one” (SODOTO) concept is used for clinical training of medical trainees. SODOTO refers to the case that having observed a particular procedure once, trainees are expected to be capable of performing the procedure and then would be able to teach the procedure for others (Kotsis, 2016). Figure 1 shows the flow of traditional skill training components. Though considered as a traditional approach, the SODOTO concept is no longer ideal for the nowadays healthcare environment, while safety is the top priority.
Many of the reported medical accidents are related to the inadequacy of knowledge, experience, or training (WHO, 2015), and these unresolved problems could be due to the shortage of medical professionals and resources. However, these medical accidents and shortage of medical resources can be addressed by the recent development of VR technology.

The case of clinical training

This paper focuses on a real case about the delivery of clinical skill training (T&S procedures) for a group of trainees, consisting of mainly fresh-graduate doctors. There are around 20 steps in clinical skill training, specifically about the procedures of T&S for blood transfusion. The process of operation is strictly standardized and requires a high level of consistency. The key processes include ‘checking patient’s identity’, ‘drawing off blood’, ‘arranging to transfer blood specimens’, and ‘sterilizing hands’, etc. (Figure 2).

Research Methodology

The T&S training is mandatory for each medical intern in the public healthcare sector in Hong Kong. The T&S training is usually delivered by a pathologist and the number of trainers in each public hospital is very limited. The training series is conducted four times per year and around 100 interns are trained every year in a hospital. The traditional T&S training design includes two main components: classroom teaching and practical sessions. The pathologist who delivers the classroom training would explain the procedures to the interns in the classroom, around 35 interns in a batch. Then the interns would practice with a blood drawing simulator, the ‘high-fidelity hand’, in a practical session under the guidance of the pathologist trainer, in a teacher to student ratio of 1:3, to ensure safety in the training. In this sense, trainees need to wait for a long time to practice with the ‘task trainer’, with one-on-one guidance. Clearly, this kind of practical arrangement is inefficient, inflexible, and especially not favorable to repetitive training.

Development of training program

The T&S training program was developed in collaboration with the public hospital in Hong Kong. The development was divided into three major stages: data collection, modelling, and programming.

In the data collection stage, essential information, including T&S descriptive procedures, videos, clinical environment, equipment, and tools, were collected at the data collection stage. With the program developers not being medical staff, it was a challenge for them to understand the details of the T&S procedures. Therefore, descriptive videos were extensively used for understanding T&S requirements and the steps involved. Other data such as environmental parameters were collected for the building of a ‘realistic’ clinical virtual environment for training.

In the modelling stage, the virtual environment was modelized to mimic the scenarios of the hospital, equipment, dressing of patients, and tools such as cleaning pack, syringe, sharp box, glove, etc. After the virtual environment was built and modeled, computer programming was performed for different actions, mimicking the various gestures in the real situation in the programming stage.

The VR Component

Unity (Unity, 2018) was used as the game engine for the application development, along with a VR system. The VR system consists of a head-mounted display (HMD) and a Leap Motion Controller (LMC). The HMD is a display device mounted on the head of users for the 3D and immersion experience. Unlike most other VR systems, the LMC is used in this project instead of the commonly used handheld controller, for the interactions with the virtual environment. Figure 3 shows the setup of the T&S VR training system. The LMC is installed in a VR developer attached in front of the HMD, as a peripheral device. It is a modern, low-cost, contact-free, and portable input device used for real-time positioning of the hands (Okazaki, 2017). The LMC is particularly important in the VR component for medical training, as it not only affects the sense of realism in the training, but also involves T&S skills practice in the grasping procedure.

VR applications are frequently used for trainees to participate in procedural practical training. VR teaching content is mainly dependent on the process in a particular training. In the designed VR training process, the procedures of practical T&S training, as illustrated in Figure 2, were adopted in order to ensure the training can satisfy the practical guideline and align with their experience in real practice. However, in order to provide an interactive experience for the medical practitioners in regard to VR content, some elements were included to enhance the training experience. First, a warning message is displayed in the notice board when a step during training is incorrect. The trainees are required to redo with the correct procedure. Second, the previous step will be restored when the virtual tools falls onto the ground accidently in order to remind the trainees to use a clean tool in a real situation, Third, a report is generated upon completion of the training.

Implementation

To justify the effectiveness and feasibility of the developed framework, pilot implementation was carried out among a group of medical interns from the public hospital. The interns were trained at the simulation and skills centre in the public hospital. The selected interns from the centre were invited to participate in the pilot implementation voluntarily.

In the beginning, a 5–10 minutes briefing was given to the group for the basic operational procedures, to impact the participants with basic knowledge. In addition, a tutorial was also provided to give participants practical knowledge of the operations. Learners could start whenever they were ready.

There were two levels in the training: beginning and advanced levels respectively. For the beginning level, the trainees were reminded of the procedures of T&S on a notice board displayed in front of them, see Figure 4. For the advanced level, there was no reminder given to the trainees and they needed to remember all the procedures for the entire training cycle.
In this study, the trainees attending the beginning level training were the targeted respondents. Right after the training session, a survey was conducted to study the teaching content, motivation, and enhanced readiness, as perceived by the participants.

A questionnaire was designed based on the relevant literature and experience of the trainers. A pilot study was carried out prior to the data collection. The questionnaire consists of two sections: the first section is about demographic information of the respondents and the second section includes 9 questions for participant perceptions on teaching content, motivation, and enhanced readiness.

Evaluation

In the investigation, we designed a questionnaire to obtain feedback from the participants. The core section of the questionnaire consists of 9 questions to investigate 3 measured variables. Among these 9 questions, each variable made use of 3 questions to determine the participant perceptions on teaching content, motivation, and enhanced readiness. The list of 9 questions for 3 measured variables used in this study are summarized in Table 1. The 7-point Likert scale was used to allow the individual to express how much they agree or disagree with the particular question. Finally, the demographic questions such as age group, gender group, etc. were also collected for participant segmentation.

Measurement

Several variables that reflect the characteristics of procedural training were selected as the measurement variables. The structural dimension was mainly measured from the internal and external interactions of VR assisted training. The relationship dimension was measured primarily in terms of class and training norms. The measurement has no mediator variable and this study divided the variables into content (C), motivation (M), and enhanced readiness (E).

The measurement variables were determined based on the research framework from the literature in education and training. Despite being difficult to draw a conclusion on specific education frameworks for VR training for professional participants, training content is crucially important as it influences what kinds of knowledge are delivered and how much training content can the trainees understand (Loewenberg Ball et al., 2008; Glyn, 2018). Cochrane (2017) conducted a design-based research framework to investigate the content of virtual reality learning environments, and the VR based content was the key element in the investigation.

Besides, motivation is believed to be the core element for the effectiveness of a trainee's learning. Motivation is not only driving trainees' behaviour, but also arouses and directs their energies to participate and improve themselves in different ways (Dinibutun, 2012). The differences in once motivation are the core reason of the diversity of their performance in classrooms, differences in trainee's prior knowledge, ability, or developmental readiness (Seifert, 2012). On the other hand, the readiness of learners is important in performing VR training. Competencies in VR technology and their readiness are the key factors to enhance students' satisfaction and retention, while motivation is the key issue for student participation (Makransky, 2019). Learner's readiness not only refers to their readiness in participating in class, affecting their initiative to learn and improvement, but also their acceptance in adopting and participating in technological training (Sagnier 2020). Factors and the corresponding measurement items contributing to practitioner content, motivation, and enhanced readiness in the VR training were determined based on the above educational framework of theories, as well as those summarized from Tang (2020) and Radianti (2020).

After measuring the variables, we designed a questionnaire that reflects the variables. The measurement of the structural dimension mainly involves content converted in the VR environment, motivation in using VR in the training, and enhanced readiness after using VR. We propose that the links between the content and procedures are essential in the training. The content converted in the VR environment mainly affects the motivation of the users. The measurement of motivation mainly includes 3 small items, which are “interested in”, “being initiated”, “being improved” in using VR in the training. The motivation of the users affects the level of readiness. Enhanced readiness is the measurement of technical skills being applied, and the usefulness of the training.

Results

In this study, a total of 72 valid questionnaires were received. Table 2 summarizes the characteristics of the participants. In the collected feedback, there were 34 male and 38 female participants. Most of the participants (72.2%) were aged below 25 and 38.5 % were aged 25 or above.

Reliability and Validity Analysis

To investigate the reliability and validity of the model, a reliability analysis was carried out for each of the surveyed variables, i.e. content (C), motivation (M), and enhanced readiness (E). The Cronbach's alpha test was used, and the outputs were interpreted by following the rule of George and Maller (George, 2003), which has illustrated that the acceptable level should be > 0.7, while good and excellent levels are > 0.8 and > 0.9 respectively. The reliability results of each measurement factor were all above the good acceptable level of 0.7, 0.968, 0.947, and 0.954 for C, M, and E, respectively. The validity of the survey study was performed by factor analysis. Kaiser-Meyer-Olkin (KMO) test is used to measure how suited the data. KMO values between 0.8 and 1 indicate the sampling is adequate. Our results showed that the KMO value is 0.915 > 0.8, which means the excellent fitting of the model.

The statistical analysis of each questionnaire items was also measured and is summarized in Table 3. It was found that for all measurement items, the total correlation has a high score ranging from 0.784 to 0.952. That means the correlation between each item and a scale score when that item is excluded is still very high, i.e. most of the items are > 0.9. In addition, the reliability tests based on Cronbach's Alpha if item deleted were also very high, i.e. ranging from 0.975 to 0.982. That means the measured items have very high positive correlation and reliability in the tests.

Mean scores of variables

Figure 5 illustrates a boxplot of the measured variables including content, motivation, and enhanced readiness for different ages. It was revealed that there were several outliers in the measured variables. The outliers in the data set were then removed and the mean score of the surveyed variables was re-calculated. It was found that the overall mean scores of the measured variables for the two age groups, below 25 and 25 or above were similar. Their mean score differences were 0.00, 0.01, and 0.03 for the content, motivation, and enhanced readiness respectively. There was no significant difference between their scores ($p > 0.0.5$) based on the statistical analysis. 95% confidence level were used in the investigation. From the boxplots of Figure 5, it was found that there were several outliers in the content, motivation, and enhanced readiness variables for the two age groups. These outliers were then removed from the data set in the following statistical studies.

Correlation

In order to better complete the various analyses, the data were pre-processed, and the measurement data of the absorptive capacity converted. Through factor analysis, the scores of the factors and the factor load were respectively added. All three dimensions were treated in the same way. The Pearson correlation analysis judges whether the hypothesis is established. Using C, M, and E, as shown in Table 4, the correlation analysis of the extracted common factors was performed using SPSS23.0. Pearson correlation analysis was conducted, and the results showed that all three factors were highly correlated with each other ($p = .000 < 0.01$).

Through the correlation analysis results, the correlation coefficients of content and motivation to enhanced readiness were 0.887 and 0.875, where the correlation of motivation and enhanced readiness was 0.925. The above studies showed that their correlation coefficients were positive and significant ($p = .000 < 0.01$), which means that the C, M, and E are significantly positively correlated at the significance level of 0.01.

PLS modelling

Partial least squares (PLS) modelling (Ringle, 2015) was carried out to investigate the relationship between the measured variables. All path coefficients between the latent variables in the models were positive, which indicates the positive relationships between each pair of connected factors. Bootstrapping analysis was performed to investigate the T statistics of the conceptual model. The relationship between each pair of connected factors was statistically significant at the level of 0.01. The results are summarized in Table 5.

Demographic differences

Trainees in the Queen Elizabeth Hospital were the targeted samples in this study. The sample data was collected through a combination of field investigation and face-to-face surveys. The questionnaires were distributed with 72 valid questionnaires returned.

The independent sample t-test was used to investigate the statistical difference between demographic segmentation. The age and gender differences in the measured variables were determined and a 95% confidence level was used to measure the statistical significance. After removed the outliers, there were 32 male participants and 38 females. Table 6 illustrated the gender difference between each variable. The results showed that there is no significant difference in mean score between males and females for all measured factors. Table 7 illustrated the age difference between each variable. We have divided the investigation into two age groups: below 25 and 25 or above. There were 51 participants aged below 25 and 19 from the aged 25 or above. Similarly, there was no significant difference in the mean score for all measured factors.

Discussion

In this study, we made use of the interactive VR technology for developing training programmes for the medical practitioners and interns to participate in the T&S training. Several studies have been conducted to investigate VR in healthcare or medical training. Kelay (2017) proposed to develop distributed simulation training for cardiovascular specialties. Iterative refinements in design and components were undertaken to simulate the complex training framework. Emphasis was put on the collaborative VR program design and general mean scores were used to compare the results. Khan (2018) conducted VR simulation training for health professions trainee, and proposed that VR training in combination with conventional training appears to be advantageous over VR training alone. However, very few trials were conducted and provided poor quality of evidence. Simulation training has also been used to promote nurse in handling violence workplace (Ming, 2019). To the authors best knowledge, this is the first attempt to conduct simulated practical VR training for T&S procedures. In our study, we propose a framework for content, motivation, and enhanced readiness variables to justify the effectiveness and feasibility of the developed training. At this stage, similar to Khan (2018), we propose that VR training can be undertaken in combination with conventional approaches in practical T&S training.

The study revealed that the design of the teaching content is a core reason leading to learner motivation. The results agreed with many previous research studies on the relationship between content and motivation (Burke, 1995; Albrecht, 2018). Williams-Pierce (2011) proposed that content is one of the five key elements to enhance student motivation. Despite the effectiveness of VR training on improving student motivation being well studied (Makransky, 2019), most articles considered the improvement of student motivation was mainly due to the gaming features of the VR content (Hu-Au 2018). Huang & Liaw (2011) explained that VR features and perceived usefulness variables were predictors for situated learning and motivation to learn, however not many articles considered the relationship between learning content and motivation for practical VR training. The current study indicated that the training content was important to enhance trainee motivation. This provides an important indication for our future research directions.

On the other hand, our study also found that motivation has a significant correlation with the enhanced readiness of VR practitioners. The study results also agreed with many recent articles that illustrated a direct correlation between motivation and learner readiness in participating in e-learning (Yılmaz, 2017), m-learning (Mizad, 2018), as well as other training and development approaches (Kim, 2019). Nevertheless, not much study has been conducted to determine the relationship between motivation and enhanced readiness for VR training. Despite the impact of VR application on students being widely studied (Hee Lee, 2019), investigating the factors for learner's readiness is important as it is believed to be essential prerequisite conditions for the effective learning process of learners (Dangol, 2019; Yogita, 2016). The current study provided an important implication on the development of practical VR training programs for medical practitioners. In the training of medical practitioners, besides considering the gaming elements in the training program, more emphasis should be put on the design of the content to enhance their motivation for learning, so that their readiness for participating the VR training can also be enhanced. The information provides an important indication in the design of similar practical VR training programs in the future.

The work that we have carried out in this study has several important implications in practice. We summarize these as follows:

1. The importance of practicing in groups

Despite the current setup of VR simulated training only supporting a single player for each device, in the implementation of this project, we propose to conduct the training in groups of 3-4 peers. This is because, in clinical training, the SODOTO concept is usually used for training medical trainees. Teach One refers to the student using their gained knowledge and cumulative learning experience to transfer it to their peers. Teaching the practical skills to other students helps them to reinforce the knowledge learned and develop towards mastery learning. Therefore, practicing in groups for peer sharing is important for practical training in T&S.

2. The need for practicing in the simulated training

Similar to most of the existing computer games, medical practitioners may also need to learn or practice with the VR training program such as the basic operations of the T&S

procedures beforehand. As such, the medical practitioners can focus on training and practicing the essential procedures involved in the T&S, in order to supplement the skills developed in conventional lessons.

3. Surveys are not sufficient to fully capture feedback from medical practitioners.

In spite of a questionnaire being used to capture feedback from medical practitioners that was determined as statistically reliable and valid, some scientific data such as real-time performance of individuals were not captured in real-time. Alternative methods for gaining more quantitative results included the performance scores in the training program. Besides, qualitative feedback was also commonly used to supplement scores from the feedback questionnaire, as free text is often viewed as providing more actionable information than a standardized Likert point scale in a quantitative survey.

Last but not least, we have made the following recommendation for future research. The traditional SODOTO concept is important in medical training. Peer-to-peer sharing of the simulated VR training is still essential in T&S. Further research is therefore needed to investigate into how peer learning is important in clinical training, and what are the essential measurement variables for peer learning. On the other hand, further study should be devoted into the design of the VR content by gathering and acting on feedback from medical practitioners across the key protocols to support the simulated training: VR scenarios, duration and frequency of training, training elements, etc. In addition, we suggest that additional approaches may be needed to better capture real-time performance data of the medical practitioners during the simulated VR training, such as heart beat rate, or other bio data that can be used to measure the efficiency of the training programme.

Conclusions

The project developed a VR training program for training on T&S procedures for medical practitioners. Traditionally, the SODOTO concept has been used for clinical training for many years. However, many of the reported medical accidents relate to the inadequacy of knowledge, experience, or training due to the shortage of medical professionals and resources. The traditional SODOTO approach is no longer ideal nowadays in the healthcare environment as safety is the top priority for patients and medical staff. In this project, a VR T&S program was developed to supplement the skills learned in traditional lessons, allowing medical practitioners to train and practice the essential procedures involved in the T&S. Unity3D was used as the game engine for application development. To measure the effectiveness of the VR training programme, a study was implemented in a local hospital. The medical practitioners were allowed to practice with the VR training and complete a survey right after the training. Despite different VR training programs already existing for healthcare, not much VR training has been specifically designed for T&S procedures. On the other hand, the training conceptual framework was designed together with the program in order to investigate the key measurement variables of the practitioners during training. We proposed a training concept framework with three core elements: teaching content, trainee motivation, and enhanced readiness. It was found that the factor of content is connected to the trainees' motivation, and the motivation is related to the enhanced readiness of the practitioners. The model reliability and validity were tested, with each measurement factor above the acceptable level. On the other hand, PLS was carried out to investigate the relationship between the measured variables. The path modeling results indicated good matching with the proposed conceptual framework. The results showed a statistically significant relationship between each pair of connected factors at the level of 0.01.

Despite the current study successfully developing a T&S training program and indicating a strong relationship for each factor, there are some limitations in the existing study. The current study indicated that content is the connecting factor of motivation, while motivation is the connecting factor of enhanced readiness. Despite the VR content in T&S training being well developed, detailed information on the design of the teaching content such as the VR content, VR scenarios, duration of the training, teaching elements, etc. was not studied. In the future, studies can be conducted to further investigate the design of the VR content. On the other hand, the current study only investigated 3 core measurement variables, other common learning factors such as learners' perceived learning, technology capability, self-directed learning, etc. were not studied. These factors may provide more insight into the design of the VR training and could also be included in future studies. This article studied the reliability and validity of the training model, and more data analytics such as determining the training effectiveness according to different expertise of medical practitioners, level of proficiency, other demographic differences, etc. can be investigated. Nevertheless, we argue that the current study provides valuable insights for the future development of similar VR training programs for medical practitioners.

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