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Performance evaluation of AR/VR training technologies for EMS first responders

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Abstract
The first responder training sector presents crucial difficulties on adopting "future of work" online training principles because physical (muscle) memory is considered as important as cognitive memory. It is obvious that physical memory cannot be obtained by existing screen- and paper-based trainings. This paper presents a novel training framework for first responders that leverages augmented reality and virtual reality technologies. The framework incorporates novel design thinking processes that are implemented for the design of the training experiences. In addition, a qualitative and quantitative analysis of various metrics such as performance, time on task, accuracy and learning rate are developed to analyze the effectiveness of the proposed framework. A special use case of the emergency medical services called the ambulance bus is investigated and it is shown that the proposed training methodology improved the accuracy of the first responders by a factor of 46% and the speed on executing tasks by 29%.

Keywords First responders · Training · Augmented reality · Virtual reality · Learning technologies · Evaluation

1 Introduction

The number of mass casualty and active shooting incidents has significantly increased over the recent years. From 2012, more than $103 billion are considered as a damage from natural disasters (National Centers for Environmental Information 2017). In addition, mass shootings have killed more than 203 and injured 645 individuals in USA (Schenk et al. 2014) in 14,000 separate events, categorized as mass casualty (Lankford 2016). Despite the fact that first responders are doing an excellent job to save people's lives and alleviate the impact of such disasters, a big portion of their success is mainly because of superhuman efforts of first responders and not due to well-planned training (Schmidt 2014).

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The training of first responders is still considered "analog" and the penetration of digital technologies and platforms in this industry is minimal. For example, most trainings still follow the traditional exposition-type learning based on theories and examples presented on books and slide decks (Stansfield et al. 2010). This type of trainings can enhance learning but they mainly help improve cognitive memory and not physical/muscle memory (Tabbarah et al. 2002). For the first responder sector, physical memory is considered of major importance since the majority of trainings and operations follow strict instructional designs and protocols that are repetitive in nature (Heinrichs et al. 2010). Additionally, it is extremely challenging to provide a multitude of scenarios that capture all training possibilities found within mass casualty or natural disaster events. In most cases, repetition of training is marginal due to costs which are mainly associated to logistics and the need to recreate physical scenarios where people can retrain. As a result, there is a reduction in learning efficiency and skills that are found to hold strong correlation with repetition (Kang 2016). Finally, and most important, some of the "live" training procedures—known as moulage—exposes first responders to risk of death and physical injury; indeed, 20% of fatalities are training related (U.S. Fire Administration 2016).

Over the recent years, the "future of work" concept provides to employees the necessary web platforms and technologies to work remotely without sacrificing efficiency and bonds with the employees. These concepts are widely applied in many disciplines, and first responders (FRs) are now receiving new ways of training based on learning management systems (LMS) using augmented and virtual reality (AR/VR) trainings. LMS systems are found to improve trainee retention and engagement, mainly due to the accessibility and portability of the service (Ouadoud et al. 2017). Characteristic examples for FRs include a Federal distance learning training course in Emergency Management Institute (EMI) (https://training.fema.gov/emi.aspx) and a National Training and Education Division (NTED) (https://www.firstrespondertraining.gov/frt/).

Virtual and augmented reality (VR/AR) are considered as the optimal technologies for the training and skill enhancement of FRs. One of the most important reasons is that they can also help improve muscle memory due to the ability of the user to navigate and interact in the environment. VR technologies isolate the user from the physical environment and place the user inside an immersive 3D environment. In this environment 3D objects, avatars and interactions can occur to provide the required level of immersion (Wilkerson 2008). AR technologies can be applied in headsets that use transparent lenses to allow the user to have full interaction with the real physical world but also visualize holographic content on the physical space (Yuan 2018). Another form of implementation of AR that makes it more affordable to end users is with the use of mobile phones (Sebillo et al. 2016). In this study, it was shown that even simple mobile phones with AR technology can help improve the performance of FRs. AR/VR has been used to quantify attention shifts in neurosurgical operations (Leger et al. 2017) and for enhanced surgical experiences (Sutherland et al. 2013; Daher 2017) as well as in nursing (Wuller 2017). In Santos et al. (2014), the authors provide a detailed overview of how augmented reality can improve learning experience in various sectors such as schools and other institutions. In Ali et al. (2019), the authors explore the improvement on training based on the concept of collaborative mixed reality environments.

Researchers at the National Institute of Standards and Technology (NIST) intend to make virtual reality simulations more of a reality for FRs, enabling firefighters, law enforcement officers and others to train for emergency operations and communications. In a parallel way, a combined AR/VR technology that bridge the gap between classroom instruction and live training for FRs in the Ambulance Bus is presented in (Koutitas et al. 2019), that consisted the basis of this paper. This paper goes one step beyond, and the main contributions can be summarized as:

- Two learning experiences are developed and compared focused on a special use case of First Responders
- The comparisons are performed with real field measurements
- A design thinking methodology is provided to help other researchers replicate the proposed processes
- The evaluation included both a qualitative and quantitative analysis to provide a spherical overview to the reader
- Key performance indicators (KPIs) and metrics are modeled who measure the impact of repetition on the learning process of FRs

2 The EMS ambulance bus case study

Many cities are deploying a fleet of Ambulance Busses (AMBUS) to address large-scale mass casualty events. The AMBUS is a full-size bus, converted to an ambulance serving 20 stretchered patients at one time, Fig. 1. Due to the fact there are a few AMBUS in the state of Texas, it is difficult for the AMBUS staff to get trained and keep up-to-date with any potential upgrades and modifications of the interior of the bus. Currently, AMBUS staff receives minimal training, consisting of a 20 min slide deck and a quick walkthrough the bus. Due to the high demand of the AMBUS, this walkthrough usually happens only once and the lack of repetition in training makes the work of FRs harder. Additionally, once trained, it may be months before a member of the AMBUS team is deployed to a mass casualty event, and the only training they have to guide them may already be outdated. Due to the complexity of the interior of the AMBUS and the numerous medical devices held within, it is a great challenge to keep a group of FRs well trained and familiar with the layout. The purpose of our investigation is to examine how AR/VR technologies can help improve training performance of EMS AMBUS.

3 Design thinking principles of the training framework

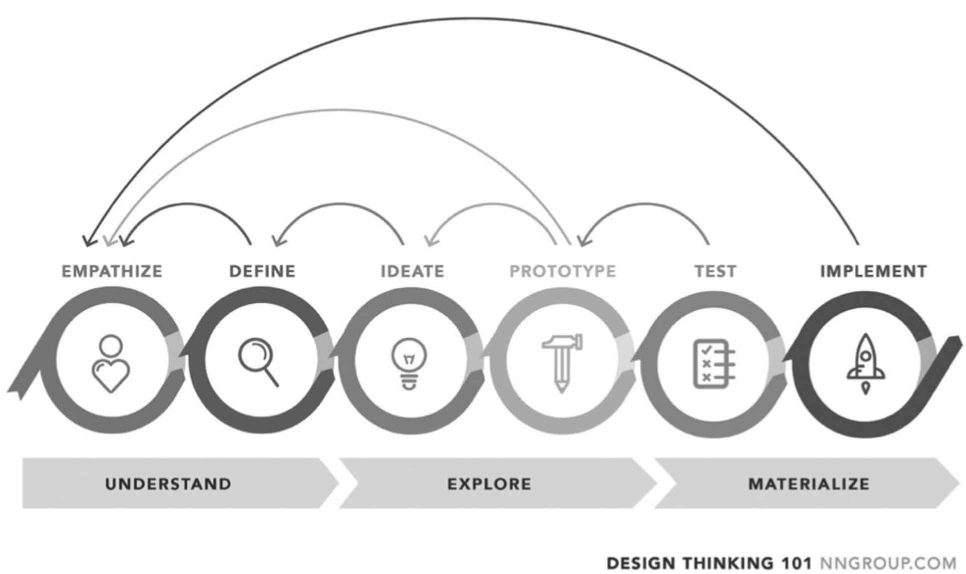
One of the challenges when new technologies are applied for the first time in interdisciplinary sectors is to maintain an equilibrium between the user needs and the product features. Design thinking (DT) methodologies are considered as a powerful tool to help interdisciplinary teams identify various user needs and pain points of the project, prioritize them and follow an agile execution plan with iterations that organize large amounts of information (Gibbons 2016). A recent study commissioned by IBM found that the introduction of DT methodologies had increased team efficiency by 75%, reduced time to market by 2 times and resulted in a return on investment of up to 300% over 5 years (Forrester Total

Fig. 1 A 360° picture inside the AMBUS

Economic Impact 2018). Despite the fact that there is a great diversity of DT methodologies (i.e., IDEO, Google Sprint, IBM Design) they all follow specific steps and phases. Each step is responsible to provide information to the adjacent step as shown in Fig. 2.

In the first phase, the team of researchers attempted to understand the user's needs. For the empathize step, the team observed current training sessions and collected after-action reports in the form of questionnaires from FRs who had been deployed in the AMBUS. Survey results noted that the majority (63.41%) of users would be Advanced Life Saving (ALS) (43.90%) and Basic Life Saving (BLS) (19.51%) EMTs. Respondents indicated that they had not had AMBUS training for 1 year or more (81.82%) and 63.64% indicated a need for more training. In addition, write-in responses showed a pattern that AMBUS personnel primarily were concerned with their performance with the AMBUS layout, infrequency of training opportunities, loading of patients, and specific equipment training. The research team reviews the collected information and defined the objectives by using Google Sprint methods such as Goal Statement, How Might We, and Ideo Method of Card Sorting. The second phase is related to the explore phase and the first step of the team was to conduct an ideation session. During this session, the team recognized the need to develop a quick prototype using 360 images, as shown in Fig. 1. In addition, the team decided to

Fig. 2 Design thinking framework for the development of AR/VR training for AMBUS



develop and test two trainings solutions, one developed in VR and one in AR.

The purpose of this study will be to examine which technology can provide improved skills to FRs. The first VR prototype was based on 360º images and a smartphone VR headset and a Web service called InstaVR. Hot spots were associated to various 360 photographs to allow the user to have a first virtual walk inside the bus, open drawers and fully view the interior. This initial prototype required very little time to produce and served as a proof-of-concept for the next iteration. User-testing sessions were conducted, with lessons learned leading to the development of both immersive VR and AR experiences using 3D models of the entire bus—allowing users to better navigate inside the bus. The visual design team created 3D rendered models of the AMBUS and individual medical items to scale. In some cases, whenever stock 3D models of medical items were available, they were purchased to save time. These models were shared by both the AR and VR version of the AMBUS. The second version of prototypes was tested with the EMTs and their instructors in order to validate the concept , the proposed features and receive user feedback. These included interface improvements, a need to collect data on how individual test subjects performed. Feedback from the AMBUS EMTs were incorporated in the final product during the materialize phase of the DT methodology. All these steps are shown in Fig. 2.

4 AR/VR training framework

The main objective of the developed training framework was to improve the efficiency of training FRs. The developed technology was designed to meet the needs of the AMBUS EMS training and offered cross platform training in both AR and VR. The overall system architecture of the proposed framework is given in Fig. 3. The AR/VR engine is the user interface between the user and the training and allows the user to navigate and interact with the 3D environment and objects and also receive tasks. An analytics engine was developed to capture raw data that are used for performance evaluation. A KPI tool was developed to compute the performance metrics used for the experiment.

4.1 Immersive training

The immersive training is a combination of a 3D environment and an instructional design, or protocol, that provides specific learning outcomes to the users. The users of the system were Cadets of the EMS Department of the City of Austin. The 3D environment incorporated objects and scenes that need to look realistic. For the purpose of our investigation, the 3D environment was the inside of the AMBUS in Texas that included the corridor, beds, medical equipment, drawers and other critical equipment utilized by EMTs. The instructional design covered the needs of memorization on critical equipment of the AMBUS, as one of the main objectives of the training was to help the cadets remember the location of equipment. A set of 10 tasks were used that were decided by the commander of the team. Thus, the training included the following tasks:

a. Find the IV supplies,
b. Find the wireless vital sign monitors,
c. Find the over the counter medication,
d. Find the narcotics safe,
e. Find trauma supplies,
f. Find the bandages,
g. Find the fire extinguisher,
h. Find oxygen supplies and oxygen regulator locations,
i. Find patient hygiene items,
j. Find bed sheets,
k. Find radios.

The training had 2 modes of operation such as the explore mode and the challenge mode. Explore mode allowed the user to explore the 3D environment without receiving any tasks from the instructional component and without being timed. In the challenge mode, the user received a task command and a timer was set to capture the time to execute the task. The challenge mode is a timed test of the Cadet's memory recall of the AMBUS systems.

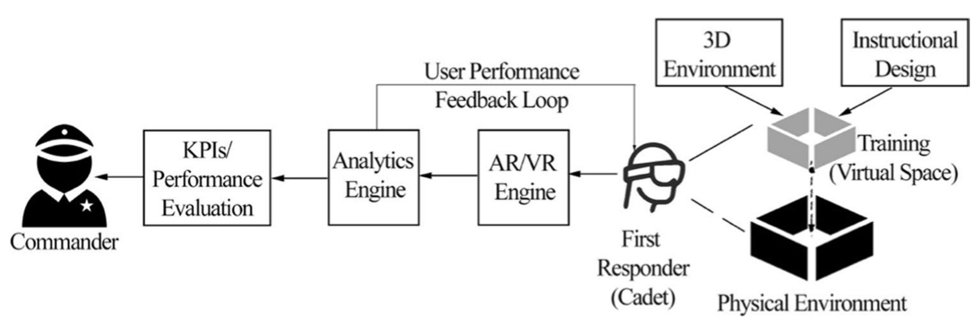


Fig. 3 System architecture of the proposed AR/VR training framework

4.2 Augmented Reality Engine

Augmented reality (AR) is considered one of the most promising technologies to help improve the performance of hands-on jobs. The reason is that it offers real-time interaction between holographic models that are overlaid on top of the real physical world. From the training perspective, AR offers a significant benefit since it improves the physical or muscle memory of the user that is proven to be important in real training scenario (Squire and Zola 1996). For example, four steps in the AR AMBUS were the same distance as four steps in the physical bus. The AR headset used was a Hololens 1.0 device with transparent lenses that project the holograms in the field of view of the user. The offered field of view was 30o which for the use case of AMBUS is acceptable due to the narrow, corridor like bus nature of the physical space of the training. The framerate of 60fps was enough to accommodate the nature of the training since it did not involve high rate requirements. The overall training was developed in Unity using C#. In the AR experience, the user was required to perform spatial mapping of their space by using the scan process of the device. For the best overall experience, the user was asked to train in a corridor to "emulate" the shape of the inside of the bus. The AR application was responsible to deploy the AMBUS in the scanned corridor. An example is shown in Fig. 4a. With the click gesture, the user was able to open or close drawers and interact with the 3D objects. A click interaction with an object during the challenge mode was assumed as a selection. In case of a correct or wrong completion of a task, the user was notified with an icon as shown in Fig. 4b. This notification was also implemented in the VR training.

4.3 Virtual reality engine

The benefit of the VR version is that it can recreate any 3D environment and experience for the user without any physical limitations. In the VR training, the headset was used to project images of an 3D rendered environment replacing the user's field of view. The used VR headset was an Oculus Rift that provided an enhanced user interaction compared to the AR Hololens. This is because two joysticks allowed the user to perform multiple gestures instead of only clicking. It should be mentioned that Hololens 2 also offers multiple gestures and a future version of the paper will examine the effect of gestures in learning. The overall training was developed in Unity using C#. A "smart watch" concept was used to allow user to observe in real time a timer that was used to calculate the time of the execution of each task (Ali et al. 2019). The VR system is designed for the Cadets to use it as many times as they like, studying the AMBUS systems and then taking the training tests over again to gauge their improvement. It should be noted that both the AR and VR headsets are commodity products that can be afford by most of the EMS teams and municipalities.

4.4 Analytics engine

The analytics engine was responsible for capturing the correct and incorrect actions of the user along with recording time on task. Every task of the training was associated to an object in the 3D environment of the AMBUS and a specific interaction with it. For the purpose of our investigation, a touch gesture interaction with the object was required to complete a task. At the end of the training session, an analytics dashboard was presented to the user in both the AR and VR experiences as shown in Fig. 4c. There are two types of raw data captured during each training and these are the number of errors and the time on task.

An error was captured when the user interacted with the wrong object of the task. For a task $i \in N$, where $N = 10$ is the total number of tasks of a training session j, a binary operator $e_i = \{0, 1\}$ was used to indicate the error and $c_i = \{0,1\}$ the correct completion of a task. It is obvious that:

$$\sum_{i=1}^{N} \left(e_i + c_i\right) = N \tag{1}$$

A timer $T_j \in \mathbb{R}_*^+$ was used to capture the total time spent in training j. A time on task indicator $t_i \in \mathbb{R}_*^+$ was used to capture the time required to execute each task of the training. It is obvious that:

$$\sum_{i=1}^{N} t_i = T_j \tag{2}$$

These data were processed by the KPI engine to provide useful insights to the commander regarding the performance evaluation of the cadets.

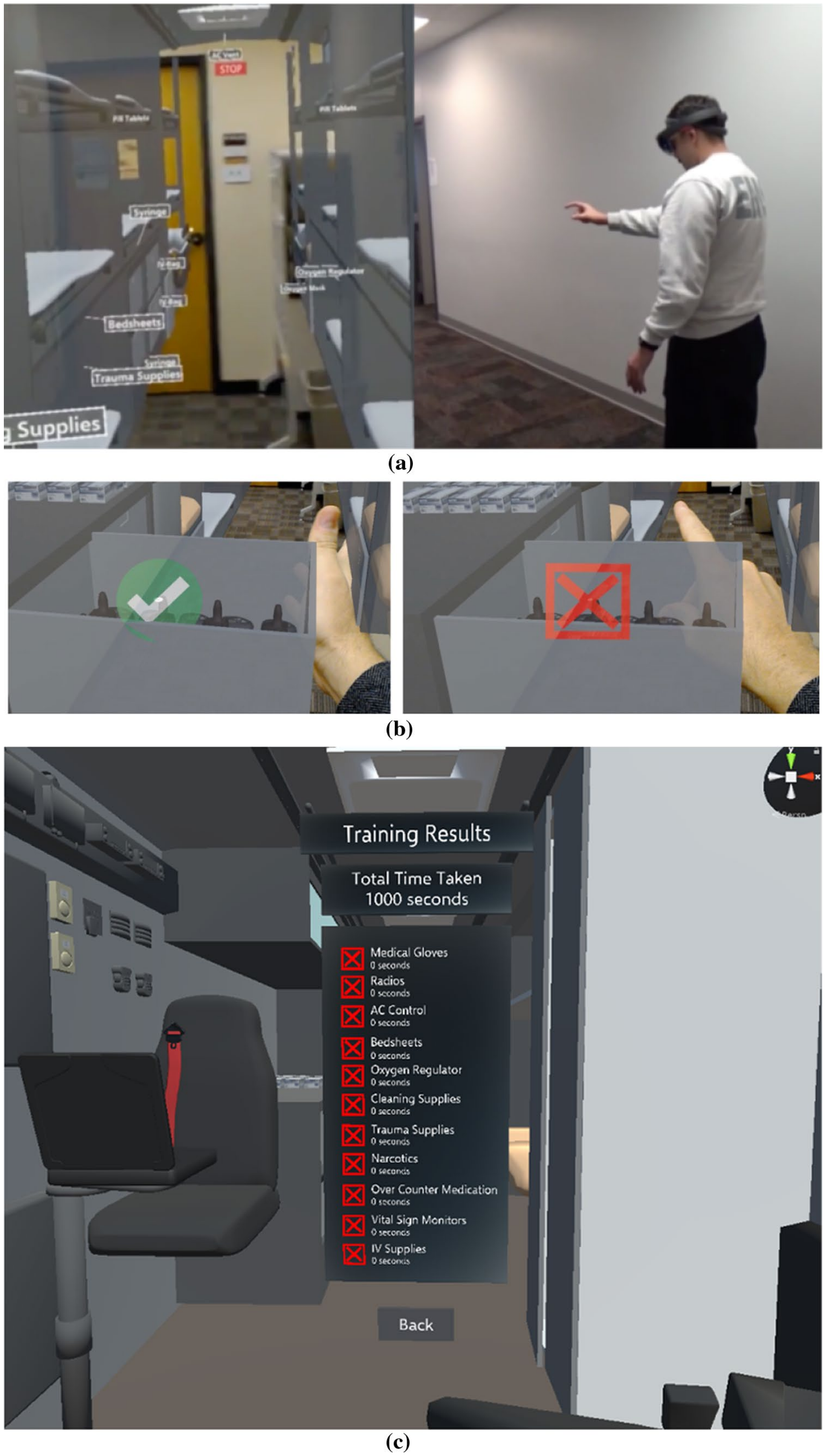
5 Key performance indicators and metrics

The number of errors and timers described in the previous section was processed to provide metrics used for the evaluation of the FR. For the purpose of our investigation, the evaluation of the training efficiency was measured by considering two different categories of KPIs related to performance and learning.

5.1 Performance metrics

Performance of FRs can easily be associated to the number of errors and the speed on executing specific tasks. The total number of errors are computed according to:

Fig. 4 **a** A user exploring the explore phase of the AR training. AMBUS is overlaid on the corridor of the building. **b** Notifications indicating correct or wrong execution of a task. **c** User in the VR training in the challenge mode. An analytics dashboard was presented at the end of each training session



$$E = \sum_{i=1}^{N} e_i \tag{3}$$

It is obvious that the accuracy can be computed as $A = 1 - {}^{E}/_{N}$. A user achieves better accuracy when the number of errors E is minimized.

The speed can be computed based on the average time on task of a training and this is given by:

$$\tau = \overline{t_i} \tag{4}$$

A cadet is assumed to be faster if the average time on task is minimum.

From one point of view, in cognitive research speed and accuracy can be the most important metrics to measure performance. But on many occasions when these variables are analyzed separately they might lead to contradictory observations about the level of performance of a FR. For example, a FR may be very accurate but so slow that they may potentially risk the life of a patient or vice versa. One way to overcome these limitations is to implement a metric that considers both accuracy and speed (Han et al. 2010). For the purpose of our investigation, this metric is given in Eq. 5.

$$P = \frac{\tau}{\left(1 - {}^{E}/_{N}\right)} \tag{5}$$

Using the above metric, a FR is considered to be fast and accurate (low-errors) when the value for P is minimum.

5.2 Learning metrics

Learning efficiency is highly correlated to the number of repetitions (Squire and Zola 1996). Since the AR/VR technology provides the cadets the ability to perform numerous opportunities for training sessions, anywhere and at anytime, it was important to observe how fast they could improve their skills by using the developed technology. The learning evolution described by the accuracy $E(s)$, speed, $\tau(s)$, and the overall performance, $P(s)$, was affected according to the number of trainigs sessions. To observe the learning evolution (speed) of FR trainees, we investigated the following metric.

Required repetitions for a percent (%) of improvement: what were the required amount of training sessions (repetitions) required to improve the performance by a factor of 50%, 75% and 90%? Thus, the team expects the values of s50, s75, and s90 such that:

$$s_{50} \to \tau\left(s_{50}\right) = 0.5 \cdot \max\left[\tau(s)\right] \tag{6a}$$

$$s_{75} \to \tau\left(s_{75}\right) = 0.25 \cdot \max\left[\tau(s)\right] \tag{6b}$$

$$s_{90} \to \tau\left(s_{90}\right) = 0.10 \cdot \max\left[\tau(s)\right] \tag{6c}$$

6 Results

6.1 Description of environment

For this goal, we focused on methods to determine whether training with a highly immersive, interactive, VR/AR system can accelerate cognitive skill acquisition in AMBUS staff. AMBUS staff were divided into three different training groups: Traditional training, AR Training, and VR training. Thirty cadets were identified who had no previous exposure to the AMBUS and were randomly assigned to the three training groups. Prior to involvement, each group received a 20-min presentation by researchers on the purpose of the research and to discuss the consent forms and study procedures. The traditional training group served as the control group and received the currently recommended training for AMBUS staff without any VR and AR training. The second group received training using the AMBUSAR and the third group received training using the AMBUSVR. In the end, all groups were tested in the same manner, multiple times to evaluate cognitive skill acquisition and cognitive transformation. The final testing was performed in the actual AMBUS with the presence of the cadet commander. Differences in test performance between the three groups were compared to assess the extent to which outcomes differ between the AR/VR-based training and traditional training methods. A short video presentation of the overall AR/VR training procedure is given in (AR/VR Demo AmBus EMS team City of Austin 2019). The cadets were able to experience the AR training at a corridor of their office space and the VR training in a 3 × 3 m space area unobstructed from objects.

All AR/VR participants received a briefing training session on using the new technology, and measures to ensure outcomes were not skewed by lack of experience or treatment fidelity issues. The commander and the cadets were all informed about the use of the AMBUSAR and AMBUSVR with a user manual presentation and an 45-min lecture and demo on the use of the technology as shown in Fig. 5a. The following measures were utilized to identify skill acquisition and impact of AR/VR environment: (1) AR/VR—observation and review; (2) ESABM situational awareness rating system; (3) presence questionnaire; (4) stress, and (5) NASA Task Load Index. Differences between training methods and training technology were assessed across all measures. The traditional group only received the current training consisting of a PowerPoint presentation and 1-h orientation of the real AMBUS. Both the AR and VR groups were given the traditional PowerPoint presentation, but only the traditional group was allowed the 1-h orientation in the real AMBUS.

(a) (b)

Fig. 5 **a** Introduction of the technology to the team with a 45 min lecture and train the trainer session. **b** In field examination on tasks and monitoring of the error and time on task by the commander

AR and VR groups were allowed to use their assigned simulations as many times as they wished for 1 week. They were asked to use the virtual simulation a minimum of 3 times in the week and asked to use it the morning of the final test. All three groups were asked not to discuss their experiences with each other during the testing procedure. Consent forms were completed and returned to the research team.

Testing was conducted in two separate locations for each training to prevent cross contamination, and participants in all three groups were asked not to discuss their experiences with each other until after the research was over. The research team was available for technical issues if they occurred during the training week. No contact was made to the research team to address technical problems. The AMBUS team was blind to which training group the participant was assigned to, potentially reducing detection bias. During the test, to record time on task, a stopwatch was started at the beginning of the task and stopped when the individual found the item(s). Errors were recorded when a participant went looking for an item in the wrong spot. Participants were given a maximum of 2 min per test question, or else an error was assumed. An example of the examination is given in Fig. 5b.

6.2 Metric analysis

The cadets inside the bus were asked to complete, in random order, the following tasks, (1) locate IV supplies, (2) locate the wireless vital sign monitoring system, (3) locate the over the counter medications, (4) locate the narcotics, (5) locate the trauma supplies, (6) locate the cleaning supplies, (7) locate the bed sheets, (8) locate the oxygen regulators, (9) locate the AC controls, (10) locate the radios. The overall performance of the cadets assuming the metric presented in Eq. 5 is presented in Fig. 6 together with the 95% confidence interval values. It should be mentioned that the lower the value of P, the better the accuracy and speed of the cadet. Recorded data indicate that the AR and VR training for most of the tasks helped the cadets improve their performance compared to that of traditional training. Table 1 presents a quantitative analysis of the accuracy (Eq. 3) and time on task (Eq. 4) for the three training methods. It can be concluded that the AR/VR technology helped cadets improve muscle and cognitive memory since both the accuracy and speed were improved during their training. More precisely, the VR technology case was more efficient and helped cadets improve accuracy by 46% compared to traditional training and the time on task by 29.3%. On the other hand, the AR technology also provided improved performance by a slightly smaller factor: Accuracy was improved by 34.5% and time on task by 10%.

An important observation is the evolution of the cognitive and physical memory with the amount of repeated training sessions (repetition), presented in Fig. 7. The figure presents the improvement of the time on task $\tau(s)$, of the cadets according to their repetitions, s. Multiple curves are presented for the individual tasks, but the most important observation arises from the average curve of all tasks for all cadets. There is a clear nonlinear relationship of learning with the repetition (Vandierendonck 2017). This means that both physical memory and cognitive memory are improved as nonlinear relation to the number of training sessions. By applying various curve fitting solutions such as linear, exponential, logarithmic and polynomial, for this use case it was found that the cadets were improving their skills with a logarithmic relationship that can be formed as:

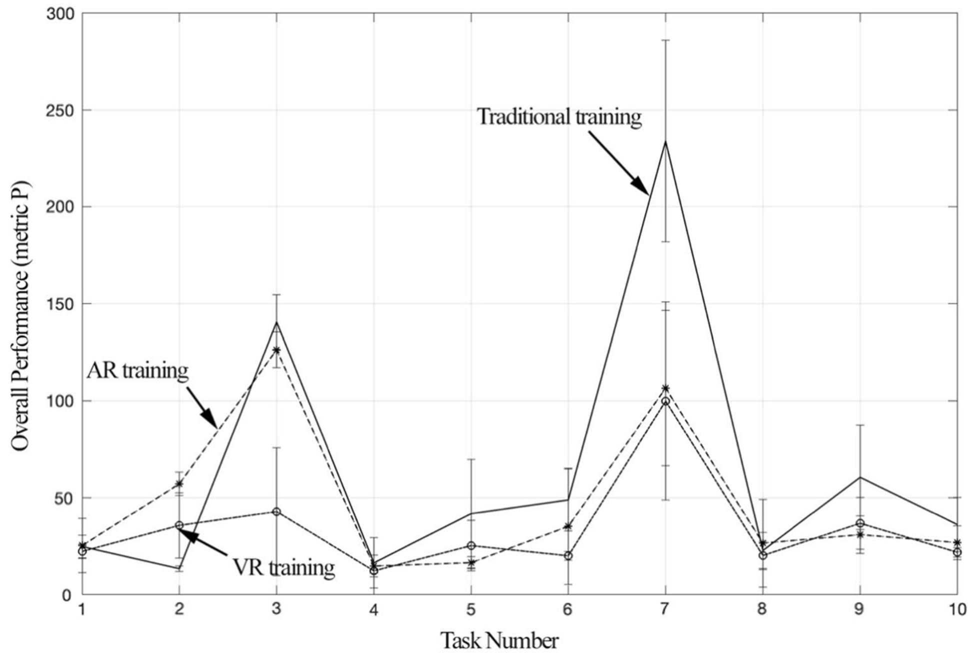


Fig. 6 Performance metric (P) for each task. The lower the P value is, the better the performance of the cadet. 95% confidence interval is also presented for each data set

Table 1 Performance comparison for three training methodologies

Type of training	Average number of errors, $\sum_{i=1}^{N} e_i$ (Eq. 3)	Average time on task, τ (Eq. 4)	Performance metric, P (Eq. 5)
Traditional training	2.16	38.2	47.5
AR training	1.41 (34.5%) improvement	34.4 (10%) improvement	39.4 (17%) improvement
VR training	1.16 (46%) improvement	27 (29.3%) improvement	30.1 (36.3%) improvement

$$\tau(s) = -0.216 \cdot \ln(s) + 0.68 \tag{7}$$

An important observation is presented in Table 2 that showcases the required number of repetitions required for a cadet to improve skills by a factor of 50%, 75% and 90%.

An interesting observation is that the VR training helped first responders perform better compared to the AR training. Despite the fact that the AR technology empowers the user with the ability to physically move in the real space and also interact with holograms, creating an immersion level that may be considered more realistic compared to VR, the overall performance of the AR was smaller than the VR. There might be various reasons why this outcome was met and someone could justify by considering the available types of gestures and the examined tasks. For example, in AR, the only available gesture is "click," whereas in VR, the user can actually move the hand and open the virtual drawer object of the training. The "click" approach may have confused the users, whereas VR provided a better foundation for the memorization of tasks inside drawers of the AMBUS. In addition, the graphics of the VR headsets and the realism of the virtual space outer perform those of the AR. Thus, some tasks that are related to visual understanding might be more suitable for a VR type of training. These observations cannot be conclusive since a larger dataset and number of trainings should be examined, that is part of the future work of this paper. In addition, with the fast evolution of AR technology and the incorporation of better graphics and gestures, a future comparison may yield different results.

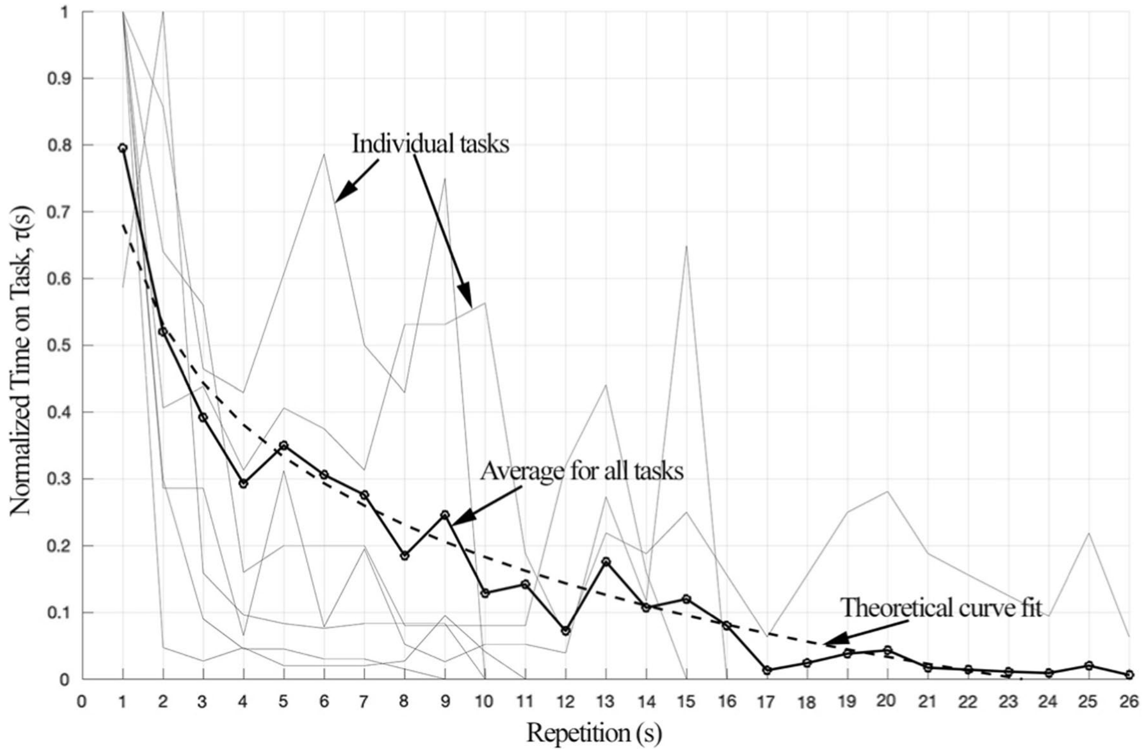


Fig. 7 Normalized time on task metric (τ) evolution for each repetition. Thin lines present the individual tasks. Solid line presents the averaged for all cadets and tasks

Table 2 Learning Progression according to Repetition

Improvement level (%)	Number of Repetitions
50	$s_{50}=3$
75	$s_{75}=7$
90	$s_{90}=14$

6.3 AR/VR and new technology adoption

A team of 15 FRs from the test groups replied to a general questionnaire to capture the need for change compared to current training. Self-report surveys yielded that 100% of respondents reported a need for additional training compared to the existing one. 47% had their last training more than a year ago indicating the lack of repetition. In addition, 33% of respondents were slightly satisfied with traditional training, and 66% of them proposed that AMBUS training should be enhanced so they can be more prepared for deployment. It is obvious that AR/VR can provide the required tool to enhance existing training.

Table 3 presents a qualitative analysis about the use of the technology by the cadets. The majority of the cadets preferred the AR/VR training and most importantly they felt prepared and confident for deployment after they completed their training.

Table 3 User adoption of proposed AR/VR training

Field	Quantity (%)	Comments
UX of AR/VR	90.9	Was somewhat or extremely easy to use
Confidence	81.8	Was somewhat or extremely to deploy after the AR/VR training
Repetition	72.73	Felt that no matter how many times they used the training, that it was helpful
Technology Preference	36.3	No preference
	27.2	Preferred traditional training
	36.5	Preferred and strongly preferred AR/VR training
Preparedness	81.2	Felt that they were prepared for the test in the real AMBUS after taking the AR and VR training
Use of AR/VR technology	90	Said they would be likely to choose a VR or AR training of another subject in the future

7 Conclusions

This proposed training framework highlighted the importance of the adoption of new AR and VR technologies in the FR sector. A special use case of EMS AMBUS was examined. Compared to existing traditional trainings that are infrequent and do not allow the cadets to repeat their trainings anywhere and anytime, it was found that the AR/VR training outperformed traditional training. The different training approaches were compared in terms of raw metrics such as the number of errors and the time on task as well as the performance metric that normalizes the error and speed metric in one formula. It was found that the VR and AR solutions helped first responders increase their skills by a factor of 46% in terms of number of errors, 29% in terms of speed and 36% as an overall performance. It was also indicated that repetition is an important reason for the overall improvement, as both cognitive and physical memory is highly correlated to the number of repeated training sessions. The methodology for developing the interactive training environments as well as the evaluation procedure described in this work can be easily adapted to larger variety of FR training situations, and the equipment required is affordable enough to be available even in small stations. Future plans of this research team include the adaptation of the training environments to mobile platforms as well as the incorporation of sensor input data to monitor the physical and affective state of the trainees during training. This will create a new layer of metrics such as cognitive load, stress evaluation and fatigue analysis that can help better estimate the efficiency of the training and the impact to first responders. With the expected penetration of AR and VR headsets in premises, it is expected that training at home can soon be an option for the first responder industry.

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