Using Augmented Reality to Train Combat Medics: An Evaluation

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ABSTRACT

This study aims to evaluate the training effectiveness of the augmented reality enabled version of the Combat Medic cards and to assist the Army in determining future development and implementation plans for augmented reality (AR) training in conjunction with the Emergency Medical Care cards or other similar training products. The University of Central Florida's Institute for Simulation and Training (UCF IST) has previously developed emergency medical training cards in an effort to design effective simulation for Army medics. Additionally, two digital supplementary versions of the cards were developed: an online Flash version and an iOS mobile eversion supporting flash card study and self-assessment with integration of study scheduling to assist with scheduling of material for transfer into long-term memory. Moreover, an augmented reality solution for the Combat Medic card deck, which will launch videos of procedures after the user scans the card was developed, with an existing third-party augmented reality toolkit that uses image recognition as a trigger. The evaluation compares learning, speed of learning, usability, perceived utility, level of engagement, and perceived speed of access to information between the augmented reality enabled Combat Medic cards and the Combat Medic app. The evaluation should provide a validated methodology for integrating AR into existing training print and/or digital training materials which can: 1) serve to expand the toolkit for Army instructional designers and trainers and 2) facilitate and continue to improve an active learning process already under development which has been well received and has already demonstrated training utility on a small scale.

ABOUT THE AUTHORS

Christina N. Lacerenza has been a researcher with the Institute of Simulation and Training since 2010, and is currently pursuing a doctoral degree in Industrial/Organizational Psychology at the University of Central Florida. Current research avenues include leadership and employee development, team training effectiveness, and scale validation.

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INTRODUCTION

The Army has long recognized the importance of training and the potential benefits that simulation may provide. When designed correctly, simulation offers another useful tool in the training toolkit. Specifically, researchers have argued for several characteristics of the simulation which drive effectiveness of its use as a training tool: (1) embedded instructional features, (2) scenarios and learning objectives are cautiously developed and embedded within the system, (3) performance assessment is existent, (4) guided learning experiences, (5) simulation fidelity parallels training procedures, and (6) a reciprocal relationship is present among subject matter experts and training experts (Salas & Burke, 2002). In efforts to design effective simulation for Army medics, the Army Research Laboratory (ARL) Human Research and engineering Directorate (HRED) Simulation and Training Technology Center (STTC) has partnered with the University of Central Florida's Institute for Simulation and Training (UCF IST) to fund and produce a system of emergency medical training cards for Army medics. Under previous contracts, three specialization decks were developed and printed: Combat Lifesaver, Combat Medic, and the Improved First Aid Kit (IFAK).

Recently, UCF IST also developed an augmented reality solution for the Combat Medic card deck that launches videos of procedures after the user scans the card. The AR application was developed with an existing third-party augmented reality toolkit that uses image recognition to activate based on the full card design, as opposed to some AR solutions that require specialized markers. When a user launches the software and points the mobile device's camera at the card, whether in print or displayed on a screen, an associated video depicting the relevant medical procedure plays.

Though initial development of the mobile AR application has been completed, evaluation of the training effectiveness of the AR component has yet to be performed. Previous iterations of the Emergency Medical Care card games have undergone preliminary evaluation studies and shown positive reception among students, as well as positive outcomes for learning both in the original print card form as well as the iOS flash card study app (e.g., Lyons et al., 2011). The current study builds on this prior work by examining the utility of implementing an augmented reality solution for learning within the Combat Medic card game. Specifically, the authors performed a comparison evaluation study between the augmented reality enabled version of the Combat Medic cards and the Combat Medic mobile application tool. This included a comparison of the mobile app with an augmented reality data, media layer, and image knowledge base that allows a combat medic to point their iOS or Android-based mobile device at a card and launch advanced media such as videos or animations showing the full medical procedure.

The current evaluation sought to determine:

1) Do individuals who are exposed to the Augmented Reality learning tool score higher on declarative and procedural knowledge tests than those who are exposed to the Mobile Application tool?
2) Do individuals who are exposed to the Augmented Reality learning tool acquire declarative and procedural knowledge more quickly than those who are exposed to the Mobile Application tool?
3) The usability and perceived utility of both learning tools (Augmented Reality, Mobile Application).
4) Do levels of engagement and self-efficacy differ based on the learning tool that individuals are exposed to?
5) The relative perceived speed of access to information provided by the different learning tools.

The current study hopes to provide a validated methodology for integrating AR into existing training print and/or digital training materials which can: 1) serve to expand the toolkit for Army instructional designers and trainers, and

2) facilitate and continue to improve an active learning process already under development which has been well received and has already demonstrated training utility on a small scale.

Rationale

Combat Medics and Lifesavers play a vital role in disaster, peacekeeping, and warfighter efforts across the globe. Providing an easy to use framework that produces the same or better learning outcomes than other traditional modalities can lead to improved performance and utilization. Getting options for physical, virtual, and hybrid Part Task Trainer study solutions can complement other curricular and advanced physical and virtual simulation elements. A design rationale that focuses on easy access, familiar interface, game mechanics, as well as learning outcomes, has produced an overall architecture that has shown positive learning outcomes and fostered positive students' reactions in past and current studies.

Following a transmedia framework allows for multiple modalities that can complement each other to produce engagement and meaningful outcomes (Jenkins, 2006; Raybourn, 2013). As an example of the flexibility and the future potential of the design rationale behind this framework, the UCF METIL team has produced a simple web interface that allows card artwork, text, and augmented reality links or media to be uploaded by subject matter experts or instructional designers to produce additional decks or quickly change content as procedures change over time. A recent example is the military's rapid request to produce a deck of cards on Ebola safety procedures in October 2014. The UCF team had less than one week to produce physical cards, a mobile app, and the augmented reality link layer pointing to Center for Disease Control (CDC) protocol even in the face of rapidly changing procedures and protocol before the kit was shipped to Liberia. This example shows the potential for the chosen design rationale to continue to have relevant impact.

METHODS

Participants

Forty-four students (35 male, 9 female) from the Florida Institute of Technology ROTC program participated in the current study. Participants' age ranged from 18 to 29 ($M = 20.5$; $SD = 2.54$). Prior to the Combat Medic intervention, participants, on average, reported neutral familiarity with the role of both Combat Medic ($M = 3.23$ [out of 5], $SD = 1.13$) and Combat Lifesavers ($M = 3.20$ [out of 5], $SD = 1.37$) within the Army. Additionally, 43.2 percent reported an interest in becoming Combat Medic certified and 61.3 percent reported an interest in becoming Combat Lifesaver certified in the future. The majority of participants reported moderate levels of technology acceptance ($M = 2.20$, $SD = 0.99$).

Training Program/Materials

Combat Medic Mobile Application

The Combat Medic mobile application is a digital version of the Combat Medic card deck that was developed for training Army medics. Combat Medic training promotes and reinforces learning of complex emergency medical technician (EMT) type treatments for saving lives on the battlefield. The Combat Medic iOS mobile version supports flash card study and self-assessment with integration of study scheduling to assist with scheduling of material for transfer into long-term memory. The application covers procedures for Combat Application Tourniquet, Combitube, Occlusive Dressing, Hemorrhage Control, Sternal Intraosseous, and Surgical Cricothyroidotomy.

Combat Medic Augmented Reality

The Combat Medic mobile application was further enhanced through the development of an augmented reality solution for the Combat Medic card deck, which launches videos of procedures after the user scans the card. The AR application was developed with an existing third-party augmented reality toolkit that uses image recognition to activate based on the full card design, as opposed to some AR solutions that require specialized markers. When a user launches the software and points the mobile device's camera at the card, whether in print or displayed on a screen, an associated video depicting the relevant medical procedure plays

Procedure

Participants were recruited from an Army ROTC program located at a small southeastern university, and data collection took place in the Spring Semester of 2015. The experimental session was approximately two hours in duration and consisted of two phases of training and three phases of measures. During the beginning of the experimental session, informed consent forms were distributed to all participants; participation was voluntary and no incentives were provided to trainees. After providing consent, trainees completed the demographic questionnaire, declarative knowledge test, procedural knowledge test, as well as a Technology Acceptance Model (TAM). The latter surveys were completed in order to establish a baseline of knowledge regarding Combat Medic medical procedures for applying a Combat Action tourniquet (CAT) and Surgical Cricothyroidotomy (SC)

Participants were randomly assigned to one of the two study conditions (Mobile Application or Augmented Reality). Both conditions had access to the same training content, and only differed in the modality through which they studied the Combat Medic content. Participants completed a 30 minute study session, with 15 minute segments assigned to one of two procedures. Upon completion of the initial study session, participants completed a set of surveys, including procedural and declarative knowledge tests. Participants were then given a five-minute break. Following the break, the second study session was implemented. Similar to the first study session, participants studied one Combat Medic procedure for 15 minutes and then switched to the remaining procedure during the second 15 minutes. The experiment concluded with completion of surveys, including the declarative and procedural knowledge tests. See Figure 1 for an overview of the experimental timeline.

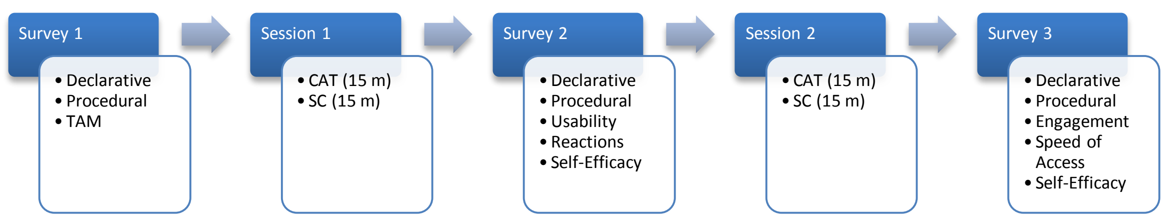

Figure 1. Experimental Session Timeline

Measures

Demographics
An 18-item questionnaire was administered to collect basic demographic information, including information about age, gender, rank, and GPA. This also included questions assessing familiarity with and interest in the role of Combat Medic/Combat Lifesaver, and general experience with touch-screen based technologies.

Combat Medic Declarative Knowledge Assessment
To assess learning of Combat Medic declarative knowledge, changes in scores on a declarative knowledge test of critical Combat Medic procedures were collected. Specifically, knowledge pertaining to the surgical cricothyroidotomy (SC) and combat application tourniquet (CAT) was assessed. This test consisted of 15 items. These items were standard multiple choice format questions and conventionally scored by awarding one point for a correct answer and zero points for incorrect answers. An overall declarative knowledge score was calculated as the sum of these 15 test items (15 possible points).

Combat Medic Procedural Knowledge Assessment
The same Combat Medic critical procedures, including SC and CAT, were the focus of the procedural knowledge test. This test required participants to sort seven different steps of the SC and CAT procedures into the correct order and was scored by awarding participants a point for each correctly sorted step. The final score was the summation of these points (seven possible points).

Technology Acceptance Model
The revised version of the Technology Acceptance Model (TAM) scale (Davis, 1989) was administered to assess perceived ease of use and usefulness of technology (see Appendix D). This scale consisted of 12 items rated on a 7-point Likert scale ranging from 1 (*extremely likely)* to 7 (*extremely unlikely).* It demonstrated an acceptable reliability

(α = 0.93).

Usability

To assess the perceived usability of the training mediums, the Computer System Usability Questionnaire (Lewis, 1995) was utilized. This measure consisted of 14 items rated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) and demonstrated an acceptable reliability (α = 0.89). The option to mark the question as non-applicable was also present.

Learner Reactions

Six items assessed participants' reactions to the Combat Medic cards on a 5-point Likert scale ranging from 1 (*very inaccurate*) to 5 (*very accurate*). An additional five yes/no formatted questions were included to assess participants' perceptions of the utility of the learning materials and whether they would use these materials if they were available after the training course. For those in the Augmented Reality training condition, one additional item was added specific to the training videos included within this condition. Finally, two open-ended questions were included in which participants were asked to indicate what they liked most and least about the Combat Medic learning tool that they utilized.

Speed of Access

Five items assessed perceived speed of access of the training medium, with three items examining speed of access as compared to technological sources and two items assessing speed of access as compared to non-technological sources. The overall measure demonstrated adequate reliability (α = 0.70). These were presented on a 5-point Likert scale ranging from 1 (*not at all*) to 5 (*to a great extent*).

Self-Efficacy

Six items captured participants' confidence associated with performing certain steps of the CAT and SC procedures. These items were presented on a 6-point Likert scale ranging from 1 (*no confidence at all*) to 6 (*complete confidence*). The measure demonstrated an acceptable reliability (α = 0.81).

Engagement

Engagement was measured with 12 items on a 5-point Likert scale ranging from 1 (*not at all*) to 5 (*very much so*). After excluding 3 items with low scale-item correlations, coefficient alpha was .75.

RESULTS

Declarative Knowledge

Table 1 presents the means and standard deviations for study variables. To assess the impact of training condition on declarative knowledge, a two-way repeated measures analysis of variance (ANOVA) was conducted. There was a significant main effect for declarative knowledge over time (F (2, 84) = 91.652; $p < .05$); however, the interaction between condition (i.e., Augmented Reality and Mobile Application) was not significant (F (2, 84) = 0.121; $p > .05$). These results are summarized in Table 2.

Table 1. Summary of All Study Variables by Condition

	Augmented Reality		Mobile Application	
Variable	***M***	***SD***	***M***	***SD***
Declarative Knowledge				
Time 1	8.14	.34	8.18	0.34
Time 2	11.10	.40	11.00	0.40
Time 3	11.59	.34	11.77	0.34
Procedural Knowledge				
Time 1	1.77	.23	1.77	0.23
Time 2	4.64	.61	6.14	0.61
Time 3	6.86	.54	7.36	0.54
Self-efficacy				
Time 1	4.36	0.17	4.11	0.17
Time 2	4.86	0.18	4.42	0.18
Usability				
Ease of Use	4.33	0.98	4.11	0.94
Utility	3.75	0.87	3.42	0.96
Design	2.00	0.69	2.36	0.79
Interface	4.38	1.01	4.52	0.69
Engagement	3.66	0.51	3.06	0.57
Speed of Access				
Non-Technology	4.02	0.64	3.89	0.83
Technology	3.46	1.03	3.48	1.27
Total	3.21	0.52	3.18	0.43

Table 2. ANOVA Results: Declarative Knowledge

Source	***df***	***SS***	***MS***	***F***	***p***
Declarative Knowledge	2, 84	310.14	155.07	91.65	.00
Declarative Knowledge X Condition	2, 84	0.409	0.205	0.121	.89

Additionally, a post-hoc least significant difference (LSD) test was conducted to indicate where significant learning changes occurred (see Table 3). Within the Augmented Reality condition, there was a significant difference between Time 1 and Time 2 declarative knowledge, but the difference between Time 2 and Time 3 declarative knowledge was not significant. In contrast, within the Mobile Application condition, Time 1 and Time 2 mean differences were significant as well as Time 2 and Time 3 mean differences. This suggests that, when utilizing the Augmented Reality modality, the second study session is not a necessary component to facilitate learning. In other words, the first study session alone is sufficient for facilitating declarative knowledge when using Augmented Reality for delivering training.

Table 3. Pairwise Comparisons: Declarative Knowledge

	Augmented Reality	Mobile Application
Variable	**Mean Difference**	**Mean Difference**
T1 - T2	-2.96*	-2.82*
T1 - T3	-3.46*	-3.59*
T2 - T3	-0.50	-0.77*

*p<.05

Procedural Knowledge

A two-way repeated measures ANOVA was performed to assess the impact of training condition on procedural knowledge. There was a significant main effect for procedural knowledge over time (F (2, 84) = 82.48; $p < .05$); however, the interaction between condition (i.e., Augmented Reality and Mobile Application) was not significant (F (2, 84) = 1.619; $p > .05$). Table 4 summarizes these results.

Table 4. ANOVA Results: Procedural Knowledge

Source	***df***	***SS***	***MS***	***F***	***p***
Procedural Knowledge	2, 84	653.65	326.83	82.48	.00
Procedural Knowledge X Condition	2, 84	12.8	6.42	1.62	.20

Additionally, a LSD post-hoc test was conducted to identify where significant learning changes occurred (see Table 5). Within the Augmented Reality condition, there was a significant difference between Time 1 and Time 2 procedural knowledge and Time 2 and Time 3 procedural knowledge. The same pattern of results was found for the Mobile Application condition. This suggests that incorporating a second study session, in addition to a first, is necessary when utilizing both modalities in order to obtain optimal procedural knowledge levels.

Table 5. Pairwise Comparisons: Procedural Knowledge

	Augmented Reality	Mobile Application
Variable	**Mean Difference**	**Mean Difference**
T1 - T2	-2.86*	-4.36*
T1 - T3	-5.09*	-5.59*
T2 - T3	-2.23*	-1.23*

*$p<.05$

Self-Efficacy

To assess the impact of training condition on self-efficacy, a one-way repeated measures ANOVA was conducted. There was a significant main effect for self-efficacy over time (F (1, 42) = 26.447; $p < .05$); however, the interaction between condition (i.e., Augmented Reality and Mobile Application) was not significant (F (1, 42) = 1.356; $p > .05$). These results are presented in Table 6.

Usability

A one-way ANOVA was performed to determine if perceived usability differed based on training condition. The results are summarized in Table 6. However, there was no significant difference between the two conditions (i.e., Augmented Reality and Mobile Application) in regards to total usability scores (F (1, 42) = 0.043; $p > .05$).

Engagement

A one-way ANOVA was conducted to assess the impact of training condition on engagement. There was a significant difference between the two conditions (i.e., Augmented Reality and Mobile Application) in regards to engagement scores (F (1, 42) = 13.53; $p < .05$) with those in the Augmented Reality condition reporting higher levels of engagement. These results are presented in Table 6.

Speed of Access

A one-way ANOVA was performed to determine if there were significant differences between the conditions based on perceived speed of access. The results of this analysis are presented in Table 6. There was no significant difference between the two conditions (i.e., Augmented Reality and Mobile Application) in regards to perceived speed of access as compared to both technological (e.g., tablet) and non-technological (e.g., manual) mediums (F (1, 41) = 0.028, $p > .05$). To assess potential differences in perceived speed of access at a more granular level, speed of access in comparison to technological mediums alone was compared across conditions. However, the results were not significant (F (1, 41) = 0.005; $p > .05$). The comparison of perceived speed of access for non-technological mediums was also not significant (F (1, 41) = 0.367, $p > .05$).

Table 6. ANOVA Results: Self-Efficacy, Usability, and Speed of Access

Source	*df*	*SS*	*MS*	*F*	*p*
Self-efficacy	1, 42	3.55	3.55	26.45	.00
Self-efficacy X Condition	1, 42	0.18	0.18	1.36	.20
Usability Total	1, 42	.010	.010	0.043	.836
Engagement	1, 42	3.97	3.97	13.53	.001
Speed of Access					
Total	1, 41	0.017	0.017	0.028	.867
Non-Technology	1, 41	0.203	0.203	0.367	.548
Technology	1, 41	0.006	0.006	0.005	.945

DISCUSSION

The current study investigated the effectiveness of both the Combat Medic Augmented Reality and Mobile Application learning tools. Specifically, the current study sought to determine:

1) Do individuals who are exposed to the Augmented Reality learning tool score higher on declarative and procedural knowledge tests than those who are exposed to the Mobile Application tool?
2) Do individuals who are exposed to the Augmented Reality learning tool acquire declarative and procedural knowledge more quickly than those who are exposed to the Mobile Application tool?
3) The usability and perceived utility of both learning tools (Augmented Reality, Mobile Application).
4) Do levels of engagement and self-efficacy differ based on the learning tool that individuals are exposed to?
5) The relative perceived speed of access to information provided by the different learning tools.

Overall, results from this study suggest that both the Mobile Application and Augmented Reality tools produce significant changes in procedural and declarative knowledge. Perceived usability of the tools and reported engagement in the training program were also rated positively. Interestingly, trainees utilizing the Augmented Reality tool reported significantly higher levels of engagement in comparison to those using the Mobile Application. However, there were no significant differences in regards to knowledge change. As such, although the Augmented Reality tool may be more engaging, this engagement does not translate into higher learning. Additionally, the perceived speed of access to information was similar across both learning tools.

Results suggest that the two modalities are equally effective in producing procedural and declarative knowledge changes, thereby suggesting that when choosing which tool to implement in the field, the learner's preference should be considered. Furthermore, cadets trained with the Augmented Reality tool reported more engagement throughout the learning process; this gives reason to suggest that implementatingthis modality may be more effective. Those trained with the Augmented Reality tool, due to their increased level of engagement, may be more motivated to transfer learned concepts in the field due to heightened levels of interest and motivation during training. Research suggests that motivation plays a large role in transfer of training (e.g., Salas & Cannon-Bowers, 2001); future studies should examine whether the Augmented Reality learning tool leads to behavioral change within a field setting.

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