Technology Acceptance of a Virtual Tactical Combat Casualty Care Simulation

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ABSTRACT

Tactical Combat Casualty Care Simulation (TC3Sim) is a serious game allowing trainees to practice TC3 procedures in a virtual environment. The current study had two primary objectives: to assess the technology acceptance of TC3Sim; and to determine the applicability of TC3Sim for medical providers who do not primarily focus on TC3, such as nurses or physicians. The study combined two common models of technology acceptance: the DeLone-McLean model of information system success (Delone & McLean, 2003) and the technology acceptance model (Venkatesh & Davis, 2000). The study population was Air Force critical care nurses (n = 22) at the University of Cincinnati Hospital and focused on the following metrics: perceived ease of use, perceived usefulness, intent to use, information quality, and system quality. Participants rated the TC3Sim platform positively across all metrics. Analyzing inter-correlation of the variables, the results showed that perceived ease of use and perceived usefulness were predictive of intent to use, consistent with similar studies. Information quality was a significant predictor of both perceived usefulness and intent to use. Notably, for many systems, such as E-commerce or webmail, information quality is not predictive of a participant's intent to use the system (Iivari, 2005); however, this was not the case for the TC3Sim application. The strong correlation in this case suggests that training systems, in particular medical training systems, are more heavily judged on the quality of presented information. Finally, the positive perceptions towards TC3Sim suggest the platform can be broadly utilized across echelons of care, including atypical TC3 providers.

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INTRODUCTION

Medical training in the military is a challenging domain, requiring innovative training solutions to prepare practitioners for treating patients in the highly stressful environment of the battlefield. The military has created a standard of practice for point of injury care, known as Tactical Combat Casualty Care (Butler, Hayman, & Butler, 1996). TC3 encompasses the skills needed to treat and stabilize battlefield casualties. TC3 focuses on treatment for the top 3 preventable deaths on the battlefield: hemorrhage control, needle chest decompression, and airway management (Champion et al., 2003). The implementation of TC3 and improvements in medical treatment devices have resulted in unprecedented survival rates for battlefield casualties (Beekly et al., 2008, Kotwal et al., 2011). However, there is substantial concern for the medical community that lessons learned from theater are not being appropriately institutionalized, potentially losing valuable information to improve patient care (Phillips, 2016). In order to rectify this and ensure that TC3 skills are preserved, the Department of Defense is preparing to train all combatants in TC3 skills, ensuring that every serviceman is able to provide initial treatment to casualties.

In order to train these skills, the Department of Defense employs a combination of training modalities. Instruction begins in the classroom with didactic content in the form of PowerPoint slides, videos, and instructor-led discussions. The didactic instruction focuses on the foundational components of TC3, which are structured into 3 phases of care: care under fire, tactical field care, and tactical evacuation care (Butler, 2015). Care under fire is the care rendered by a provider at the scene of the injury while the provider and the casualty are still under effective hostile fire, and typically comprises controlling severe extremity hemorrhage and moving the casualty to a safer location. Tactical field care is characterized by a reduced threat level and additional time to provider treatments. During tactical field care, airway management, needle chest decompression, or initiation of intravenous fluids may take place to stabilize a patient. Finally, during tactical evacuation care, the patient is prepared for transit and then evacuated to a medical treatment facility. Upon completion of the didactic instruction period, all trainees understand the phases of TC3 and the associated roles and treatments for each.

Following didactic instruction, procedural and psychomotor skills training occurs. Procedural skills focus on understanding the steps required to complete a treatment. Then, foundational TC3 knowledge and procedural skills knowledge is combined with ‘hands-on’ skills, in what is known as the psychomotor domain (Harrow, 1972). The ‘hands-on’ portion of instruction is conducted using a variety of technology, including medical mannequins and part task training devices. These training devices, or simulators, allow students to gain the psychomotor skills associated with treatment in a risk-free environment, prior to seeing a real patient. For TC3 training, this involves learning how to place tourniquets, applying bandages, performing cricothyrotomies, etc. At the end of a TC3 course, students participate in a culminating event, typically lane training, where they move as a squad through a tactical training lane, treating simulated casualties they encounter along the way.

Notably missing from most current TC3 training is a virtual component. While there have been virtual TC3 training platforms developed (Sotomayor, 2010; Brown et al., 2016), the implementation of these into the larger training cycle has lagged. However, due to the movement towards providing TC3 training for all combatants and the clear gap in virtual medical training, acquisition agencies and researchers are refocusing efforts to provide a virtual TC3 training capability for the community.

In order to ensure that a virtual simulation is adopted by the TC3 training community, it is important to assess technology acceptance. Broadly, technology acceptance refers to theories regarding how users come to accept and ultimately use a technology (Davis, 1989). This paper reports the results of a study assessing the technology acceptance of a mature, virtual TC3 simulation, known as TC3Sim. Additionally, as TC3 training is applied to all combatants, the acceptance of a TC3 simulation needs to be tested for atypical user groups, such as physicians, nurses, or non-medical personnel. To address this need, this study focused on a group of critical care nurses and physicians.

BACKGROUND

The adoption of technology into a user community is highly complex, with a myriad of individual and organizational factors impacting success. To study the reasons behind the acceptance or rejection of technologies, theoretical models and frameworks have been developed. Within this study, two common models are used to explain and predict user behavior related to technology: the technology acceptance model and the Delone-McLean information system (IS) success model.

The technology acceptance model (TAM) is built upon the theory of reasoned action, also referred to as the Fishbein model (Ajzen & Fishbein, 1980). The theory of reasoned action posits that an individual’s attitudes and subjective norms are predictive of behavior. This theory was extended by Davis to determine which metrics are most predictive of behaviors related to technology, specifically acceptance and usage (Davis, 1986). In 2000, the model was further refined in the TAM2 (Venkatesh & Davis, 2000). The variables of interest within the TAM include perceived usefulness (PU), perceived ease of use (PEU), and intent to use (IU). Perceived usefulness (PU) was defined by Davis (1989) as "the degree to which a person believes that using a particular system would enhance his or her job performance". Perceived ease-of-use (PEU) was defined by Davis (1989) as "the degree to which a person believes that using a particular system would be free from effort", which has many similarities to usability studies. Lastly, intent to use (IU) is the desire to use a technology, based upon both internal and external factors. This model has been employed to study a variety of technologies, including telemedicine (Hu et al., 1999), e-Commerce (Klopping & McKinney, 2004), email (Geffen & Straub, 1997), and many more (King & He, 2006). The TAM model is shown in Figure 1.

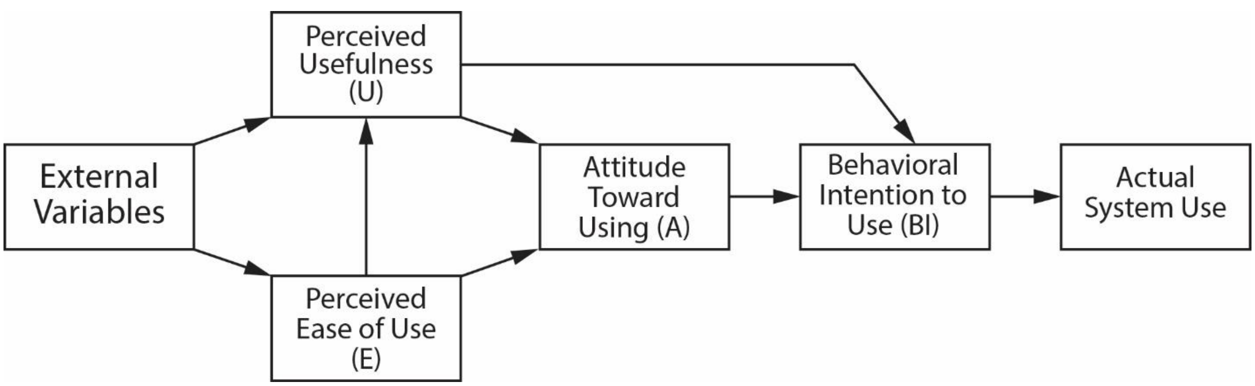

Figure 1: Technology Acceptance Model (Venkatesh & Davis, 2000)

The IS success model is an information system theory which seeks to describe the success of an information system using commonly evaluated factors (Delone & McLean, 1992). The model employs six dimensions of IS success: system quality (SQ), information quality (IQ), use, user satisfaction, impact, and benefits. System quality focuses on measures related to ease of use, ease of learning, efficiency, interactivity, reliability, and system features (McKinney, 2002; Gable et al., 2008). Information quality includes measures such as accuracy, adequacy, completeness, consistency, relevance, and understandability (Bailey & Pearson, 1983; McKinney, 2002; Gable et al., 2008). The use dimension uses measures such as time spent using the system or number of individual uses. User satisfaction concentrates on enjoyment, overall satisfaction, and effectiveness (Almutairi & Subramanian, 2005). Finally, impact and benefits utilize measures of job performance, job effectiveness, and productivity (Iivari, 2005). The IS success model has also been used extensively to assess IS systems, including finance (Iivari, 2005), telemedicine (Hu, 2003), and numerous other others (Dwived et al., 2011). The IS success model is shown in Figure 2.

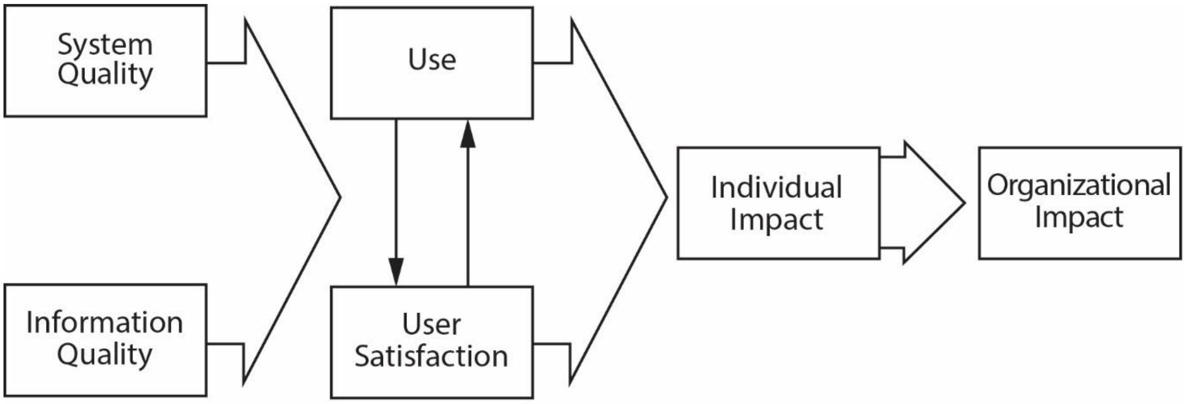

Figure 2: Information System Success Model (DeLone & McLean, 1992)

While both the TAM and IS success models have been widely studied, technology adoption models have been seldom applied to training systems. Research has been conducted on knowledge management systems (Clay et al; Jennex & Olfman, 2010) and an e-Learning system (Lin, 2007). However, the domain of training is largely unexplored in the lens of adoption models, especially for virtual and physical simulations. This study seeks to begin the discourse of how these models might be utilized to gain insight on training system adoption, and whether the models need alteration to be suitable for the domain of training.

METHOD

The virtual simulation used within this study is TC3Sim. The gameplay is a 'first-person thinker', requiring the user to triage and treat casualties in a simulated battlefield environment. The interface is a wheel-based menu system. To initiate treatment actions, the user selects a body area, then the content of the wheel menu updates to the corresponding treatment options for that body area. For example, if the user clicks on a leg, there would be options including applying a tourniquet or removing clothing to expose the lower limb. A screenshot of the application and the wheel menu is shown in figure 3. Following each scenario, an after action review capability provides users with a report on their in-game choices, including what they did correctly / incorrectly and actions they neglected to take. During this study, the application was installed on 12 Dell Latitude E6610 laptops with Windows 7 operating systems. External mice were used rather than a trackpad to make game navigation less cumbersome. Participants were given headphones to allow audio from the game to be directed to individuals, rather than ambient audio through the internal speakers of the laptop.

Figure 3: TC3Sim

The study was conducted at the University of Cincinnati Hospital, with the computer set up in a single room. Participants were given a short brief upon entry on the purpose of the study. Following the brief, participants completed a tutorial scenario in TC3Sim, which guides users through the controls of the simulation using voice narration. Additionally, the tutorial covers the treatment options within the TC3Sim application. Once the tutorial was completed, participants completed two scenarios: an introductory, single-casualty scenario with a single wound; and a more complex, multi-casualty scenario. This experimental design allows participants to: learn the basics of the simulation in the tutorial; to experience the application in the context of a less stressful patient encounter; and then ultimately progress to a much higher stress multi-patient event. This is consistent with accepted training frameworks, such as stress exposure training (Driskell & Johnson, 1998) or crawl-walk-run. Following these scenarios, participants completed a short demographics survey and a survey related to the TAM and IS success model.

During this study, a composite model was used to provide the usefulness, ease of use, and intent to use data from TAM, while still gaining insight into the system quality and information quality factors from the DeLone-McLean model of IS success. Since this study did not include long-term use data, the model concludes with behavioral intention to use. The model is shown in figure 4. To assess these model factors, the study employed a 16 item Likert-scale survey with a range of five response choices from strongly disagree (1) to strongly agree (5). A single item was reverse coded, to ensure that respondents were thoroughly reading and thoughtfully responding to the survey questions. The survey utilized questions from both the TAM and the IS success models. To assess ease of use, usefulness, and intent to use, 10 items were included from a validated survey instrument from Marsom (2007). The questions for ease of use (α=0.89), usefulness (α=0.89), and intent to use (α=0.85) have been shown to be reliable. To assess system quality and information quality, 6 items were adapted from a survey instrument from Doll & Torkzadeh (1998). The questions for system quality (α=0.90) and information quality (α=0.87) have also been shown to be reliable.

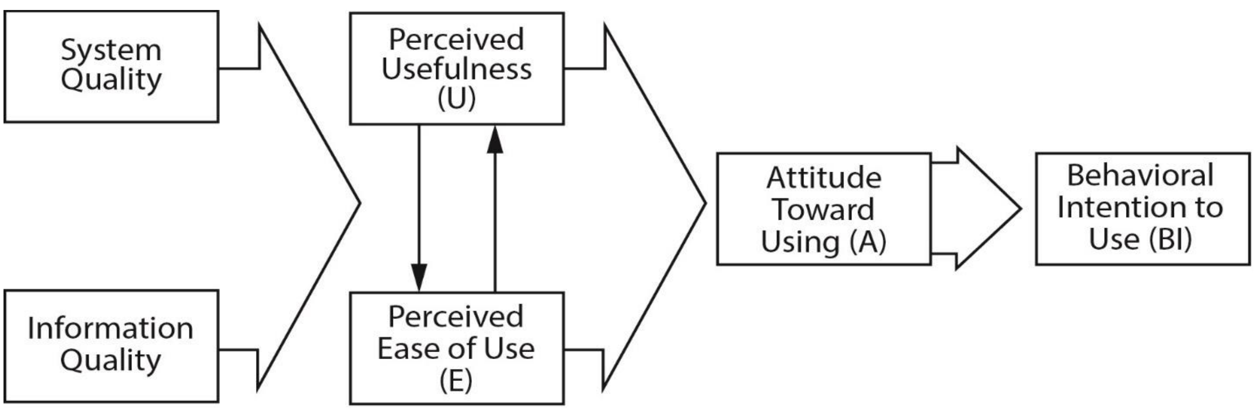

Figure 4: Composite acceptance model based on TAM and DeLone-McLean IS Success model

RESULTS

The study included a total of 22 participants – 20 critical care nurses and 2 physicians. The average age of participants was 33 years old. There were 11 female and 11 male participants in the study. The majority of participants (19) indicated that they played video games less than 1-2 times a month, with 10 indicating they never play video games. Only 3 participants indicated they played video games daily or weekly.

To begin the data analysis, the mean response for each participant was calculated for the measures of system quality, information quality, perceived usefulness, perceived ease of use, and intent to use, as well as an overall average. Using these averages, researchers classified participant feedback as a positive response, negative response, or neutral response for each of the technology acceptance measures. An average response below three was categorized as negative, above three were categorized as positive, and exactly 3 were deemed as neutral. The survey results indicated positive responses from nearly all participants for all of technology acceptance measures. For ease of use, 20 out of the 22 participants reported a positive response, while two responded negatively. Usefulness was viewed positively by 21 participants, with one neutral participant. System quality and information quality were unanimously rated positively. Intent to use had 19 positive responses, 2 neutral responses, and 1 negative response. The overall response was positive from 21 participants, with one neutral response. The ratio of positive, negative, and neutral responses are shown graphically in figure 5.

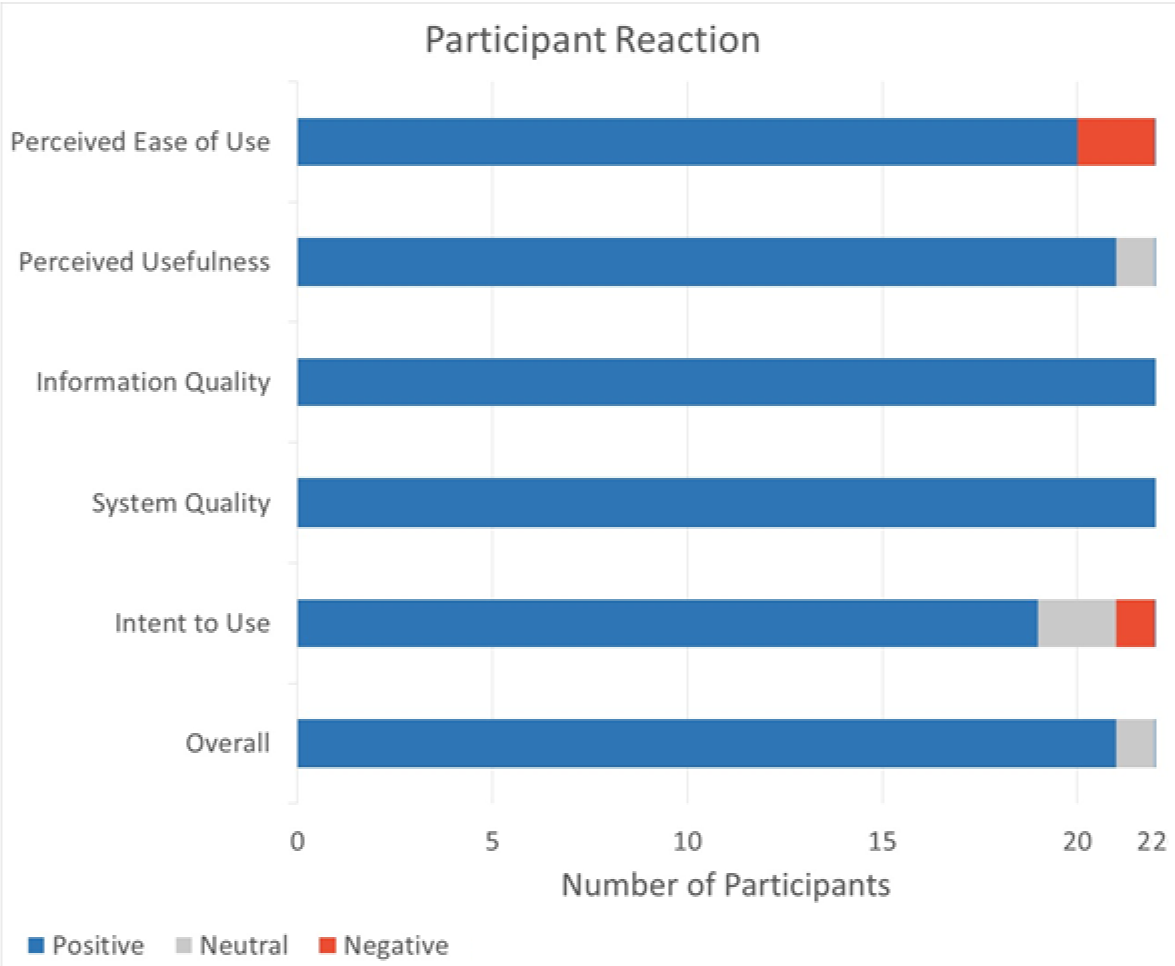

Figure 5: Participant Response for Individual Technology Acceptance Metrics and Overall System

Looking at the mean response data without classification as positive, negative, or neutral, the results indicate a significantly positive response. The mean and standard error for each of the factors is shown in table 1. As a reminder, a score of 5 is the largest positive response for a factor, while a score of 1 is the most negative response.

Table 1: Mean Rating for Individual Technology Adoption Factors and Overall System

Measure	Mean	Standard Error	N
Perceived Ease of Use (PEU)	4.11	0.16	22
Perceived Usefulness (PU)	4.09	0.12	22
Information Quality (IQ)	4.42	0.08	22
System Quality (SQ)	4.45	0.12	22
Intent to Use (IU)	4.27	0.17	22
Overall	4.21	0.14	22

As indicated by the high percentage of positive responses and the positive mean response values, the system seems to have a high degree of technology acceptance from the test population. In order to gain insight into the acceptance model, the correlation between metrics was calculated using the Pearson correlation coefficient, or Pearson's R. Pearson's R is a measures of linear correlation between two variables, ranging from +1 to -1. An R value of +1 is a total positive correlation, a value of -1 is a total negative correlation, and a value of 0 shows no correlation. In general, values above +0.7 are considered strong positive correlations, between +0.3 and +0.7 are moderate correlation, and below +0.3 are weak to no correlation. The strongest correlation was between information quality and perceived usefulness, r=0.84, p<.001. Additionally, the relationship between perceived ease of use and perceived usefulness showed strong correlation, r=0.71, p<.001. Lastly, the intent to use variable was strongly correlated with perceived ease of use (r=0.73, p<.001), perceived usefulness (r=0.78, p<.001), and information quality (r=0.75, p<.001). The full matrix of inter-correlation between the technology acceptance metrics is shown in table 2.

Table 2: Inter-correlation of Technology Adoption Metrics

	PEU	PU	IQ	SQ	IU
PEU	1				
PU	0.718*	1			
IQ	0.438***	0.846*	1		
SQ	0.683*	0.591**	0.447***	1	
IU	0.739*	0.782*	0.757*	0.665*	1

*p<.001; **p<.01; ***p<.05

CONCLUSION

The results of the study indicated that the TC3Sim application demonstrated a high degree of technology acceptance. Both the measures from the TAM and the IS success models showed a positive response from the majority of the test population. Additionally, the mean response across the population was very positive for all measures, with all averages above 4. This indicates acceptance was high, rather than a moderate acceptance with ratings towards the middle of the scale at 3. Focusing on the final step of the composite acceptance model, intent to use was positive for all participants but one, which was neutral. These results indicate that should this population have access to the TC3Sim application, they would use it. Since this is an atypical population, this gives credence to the notion that a virtual TC3 simulation could be used to train TC3 procedures across the wider military population.

When using an adoption model, it is important to look at the variables which are highly correlated to understand which variables might serve as predictors. In this case, we are most concerned with variables that are predictive of intent to use. Results showed that perceived ease of use, perceived usefulness, and information quality are all highly predictive of intent to use. Additionally, while not above the r>0.70 threshold, system quality (r=0.665, p<.001) demonstrated a moderate to strong correlation with intent to use. These findings are in line with the current body of knowledge. Other researchers have shown perceived usefulness is highly predictive of intent to use and ultimately technology usage (Hu, 1999). Further, perceived ease of use typically shows a direct effort on the perceived usefulness measure, thereby indirectly affecting intent to use. The results from this study mirror those findings.

Of note, information quality is typically not strongly correlated with intent to use or ultimately usage in systems such as e-Commerce or webmail (Iivari, 2005). However, in this case, information quality is highly correlated with both perceived usefulness and intent to use. One potential explanation for this is the heavy reliance on quality information in a training system. Since the main goal of a training system is to impart knowledge or skills, it makes logical sense that information quality would be a driving factor for acceptance among a training population; whereas with e-Commerce or webmail, there is less reliance on the completeness or accuracy of the information.

An integral component in the adoption of a training system is instructor buy-in and curriculum design. In this study, the participants were in the role of students learning the concepts of TC3. However, in a training environment, the use of training assets is generally at the discretion of the instructor. The student's time is planned in advance, with time allotted for classroom instruction or 'hands-on' instruction. Thus, it would be equally important to have a measure of instructor acceptance on a training system. Further research is needed to determine whether the model employed in this study would be sufficient, or if an instructor acceptance model would be needed.

There were limitations in this study which should be noted. To begin, with a sample size of 22, it is difficult to make definitive conclusions. While the correlation statistics are significant for this population, it would require a larger sample to ensure that these results and conclusions can be generalized across broader populations. For example, since the test population generally did not frequently play video games, the data may be skewed towards non-gamers. The other limitation is the lack of usage data. Since the study concluded at the stage of behavioral intent to use, there is no data on whether users actually use the application, rather than simply believing they would. As such, the correlation between intent to use and actual use cannot be deduced.

In summary, the TC3Sim application demonstrated a high degree of technology acceptance as a training system. Additionally, by using a test population which typically doesn't receive extensive TC3 training, the study demonstrated that atypical populations may be accepting of the application. The combination of the TAM and the IS success model was useful in determining meaningful relationships between technology adoption measures, reinforcing the predictive values of perceived usefulness and perceived ease of use seen in domain literature. The significant predictive value of information quality seen in the study is notable, with the potential finding that users of training systems have different behavioral patterns and place more value on the quality of information in a system. Future research is needed in this area, including a larger sample size, the inclusion of usage data, and the inclusion of instructor acceptance data.

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REFERENCES

Almutairi, H., & Subramanian, G. H. (2005). An empirical application of the DeLone and McLean model in the Kuwaiti private sector. *Journal of Computer Information Systems*, *45*(3), 113-122.

Ajzen, I., & Fishbein, M. (1980). Understanding attitudes and predicting social behaviour.

Bailey, J. E., & Pearson, S. W. (1983). Development of a tool for measuring and analyzing computer user satisfaction. *Management science*, *29*(5), 530-545.

Beekley, A. C., Sebesta, J. A., Blackbourne, L. H., Herbert, G. S., Kauvar, D. S., Baer, D. G., ... & 31st Combat Support Hospital Research Group. (2008). Prehospital tourniquet use in Operation Iraqi Freedom: effect on hemorrhage control and outcomes. *Journal of Trauma and Acute Care Surgery*, *64*(2), S28-S37.

Brown, R., McIlwain, S., Willson, B., & Hackett, M. (2016, May). Enhancing Combat Medic training with 3D virtual environments. In *Serious Games and Applications for Health (SeGAH), 2016 IEEE International Conference on* (pp. 1-7). IEEE.

Butler, F. K., Haymann, J., & Butler, E. G. (1996). Tactical combat casualty care in special operations. Association of Military Surgeons of the US.

Butler, F. K. (2015). Tactical combat casualty care. *Encyclopedia of Trauma Care*, 1548-1551.

Champion, H. R., Bellamy, R. F., Roberts, C. P., & Leppaniemi, A. (2003). A profile of combat injury. *Journal of Trauma and Acute Care Surgery*, *54*(5), S13-S19.

Davis Jr, F. D. (1986). A technology acceptance model for empirically testing new end-user information systems: Theory and results (Doctoral dissertation, Massachusetts Institute of Technology).

Davis, F. D.; Bagozzi, R. P.; Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35: 982–1003*, doi:10.1287/mnsc.35.8.982

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13 (3): 319–340*, doi:10.2307/249008

DeLone, W. H., & McLean, E. R. (1992). Information systems success: The quest for the dependent variable. *Information systems research, 3(1),* 60-95.

Doll, W. J., & Torkzadeh, G. (1998). Developing a multidimensional measure of system-use in an organizational context. *Information & Management*, *33*(4), 171-185.

Driskell, J. E., & Johnston, J. H. (1998). *Stress exposure training. Making decisions under stress: Implications for individual and team training*, 191-217.

Dwivedi, Y. K., Wade, M. R., & Schneberger, S. L. (Eds.). (2011). *Information Systems Theory: Explaining and Predicting Our Digital Society (Vol. 1)*. Springer Science & Business Media.

Gable, G. G., Sedera, D., & Chan, T. (2008). Re-conceptualizing information system success: The IS-impact measurement model. *Journal of the association for information systems*, *9*(7), 377.

Gefen, D., & Straub, D. W. (1997). Gender differences in the perception and use of e-mail: An extension to the technology acceptance model. *MIS quarterly*, 389-400.

Harrow, A. J. (1972). *A taxonomy of the psychomotor domain: A guide for developing behavioral objectives*. Addison-Wesley Longman Ltd.

Hu, P. J., Chau, P. Y., Sheng, O. R. L., & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of management information systems*, *16(2*), 91-112.

Hu, P. H. (2003, January). Evaluating telemedicine systems success: a revised model. In System Sciences, 2003. *Proceedings of the 36th Annual Hawaii International Conference on (pp. 8-pp)*. IEEE.

Iivari, J. (2005). An empirical test of the DeLone-McLean model of information system success. *ACM Sigmis Database*, 36(2), 8-27.

Jennex, M. E., & Olfman, L. (2010). A model of knowledge management success. ME Jennex & S. Smolnik, eds. *Strategies for Knowledge Management Success: Exploring Organizational Efficacy*. IGI Global, 14-31.

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & management*, 43(6), 740-755.

Klopping, I. M., & McKinney, E. (2004). Extending the technology acceptance model and the task-technology fit model to consumer e-commerce. *Information Technology, Learning, and Performance Journal*, *22(1)*, 35.

Kotwal, R. S., Montgomery, H. R., Kotwal, B. M., Champion, H. R., Butler, F. K., Mabry, R. L., ... & Holcomb, J. B. (2011). Eliminating preventable death on the battlefield. *Archives of surgery*, *146*(12), 1350-1358

Lin, H. F. (2007). Measuring online learning systems success: Applying the updated DeLone and McLean model. *Cyberpsychology & behavior*, *10*(6), 817-820.

Lin, W. S., & Wang, C. H. (2012). Antecedences to continued intentions of adopting e-learning system in blended learning instruction: A contingency framework based on models of information system success and task-technology fit. *Computers & Education*, 58(1), 88-99.

McKinney, V., Yoon, K., & Zahedi, F. M. (2002). The measurement of web-customer satisfaction: An expectation and disconfirmation approach. *Information systems research*, *13*(3), 296-315.

Masrom, M. (2007). Technology acceptance model and e-learning. *Technology, 21*(24), 81.

Phillips, M. (2016). Military Doctors Fault Pentagon on Battlefield Casualty Care. *Wall Street Journal*. Retrieved June 1, 2017 from https://www.wsj.com/articles/military-doctors-fault-pentagon-over-battlefield-casualty-care-1452194963.

Sotomayor, T. M. (2010). Teaching tactical combat casualty care using the TC3 sim gamebased simulation: a study to measure training effectiveness. *Studies in health technology and informatics*, *154*, 176-179.

Venkatesh, V.; Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46 (2): 186–204,* doi:10.1287/mnsc.46.2.186.11926