ORIGINAL RESEARCH

Augmented Reality Demonstration Survey Results From a Veteran Affairs Medical Center

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Background: Augmented reality (AR) has a wide range of potential applications to enhance health care. Understanding how the introduction of a new technology may impact employees is essential for overall health care system success.
Methods: Survey responses were obtained before and after a health care–focused interactive AR demonstration at a US Department of Veterans Affairs (VA) medical center. Data were assessed with descriptive statistics, Wilcoxon signed rank matched pairs test, pooled *t* test, and analysis of variance.
Results: A total of 166 individuals participated in the demonstration and survey. Statistically significant improvements were seen after the use of the new AR technology in each of the categories assessed using a 5-point Likert scale. Scores for perceptions of institutional innovativeness increased from 3.4 to 4.5 (a 22% increase; $P < .001$); employee excitement about the VA increased from 3.7 to 4.3 (a 12% increase; $P < .001$); and employee likelihood to continue working at VA increased from 4.2 to 4.5 (a 6% increase; $P < .001$). Subgroup analysis demonstrated statistically significant differences by employee veteran status, VA tenure, and gender. Respondents felt strongly that this type of work will positively impact health care and that the VA should continue these efforts.
Conclusions: An AR demonstration significantly increased employee excitement and intention to continue employment at the VA and provided valuable insights about the most impactful uses of AR in health care.

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Building the health care system of the future requires the thoughtful development and integration of innovative technologies to positively transform care.[1-4] Extended reality (XR) represents a spectrum of emerging technologies that have the potential to enhance health care. This includes virtual reality (VR), where a computer-generated visual experience fills the screen; augmented reality (AR), which allows users to see computer-generated images superimposed into an otherwise normal real-world field of view; and mixed reality (MR), which allows users to interact and manipulate computer-generated AR images.

Clinicians and researchers have begun exploring the potential of XR to address a wide variety of health care challenges. A recent systematic review concluded that many clinical studies in this area have small sample sizes and are in the preclinical, proof-of-concept stage, but demonstrate the potential and impact of the underlying VR, AR, and MR technologies.[5] Common emerging health care uses for XR include medical education, training, presurgical planning, surgical guidance, distraction therapy for pain and anxiety, and home health indications, including rehabilitation.[5-39] A scoping review of emerging health care applications for XR technologies is provided in eAppendix, available at doi:10.12788/fp.0364.

Importantly, some researchers have raised concerns regarding the adaptability of the health care workforce with emerging technologies, and their interest in new methods of delivering care.[7,39] Successful deployment of any novel health care technology depends on multiple factors, including alignment with staff needs, receptivity to those solutions, customization to specific preferences, and usability.[1,3,40-42] Unfortunately, the implementation of some health care technologies, such as electronic health records that did not account for end-user requirements, resulted in employee fatigue, burnout, and negative staffing turnover.[42-44] Conversely, elevated employee morale and operational performance have been directly linked to a climate of inclusion and innovation.[45-47] In this assessment, we sought to understand US Department of Veterans Affairs (VA) employees' perceptions and expert opinions related to the introduction of new AR/MR technology.

METHODS

VA Palo Alto Health Care System (VAPAHCS) consists of 3 inpatient hospitals and 7 outpatient clinics, provides a full range of care services to > 90,000 enrolled veterans with 800 hospital beds, 3 nursing homes, and a 100-bed domiciliary. The facility also runs data-driven care projects in research, innovation, and evidence-based practice group under nursing services.[48] This project was performed by the VA National Center for Collaborative Healthcare Innovation at the VAPAHCS campus.

The combined technical system used for this assessment included a wireless communication network, AR/MR hardware, and software. Medivis AnatomyX software displayed an interactive human anatomy atlas segmented into about 6000 individual interactive parts. Medivis SurgicalAR received US Food and Drug Administration clearance for presurgical planning and was used to transform and display deidentified diagnostic images (eg, magnetic resonance images and computed tomography) in 3-dimensional (3D) interactive holograms. The wireless Microsoft HoloLens 2 AR/MR headset was used for viewing and sensor-enabled collaborative interaction. Multiple participants in the same physical location simultaneously participated and interacted with 3D holograms. The interactive hologram data were enabled for 3D stereoscopic viewing and manipulation.

Setting and Participants

We reviewed published studies that used questionnaires to evaluate institutions' level of innovation and new technology user acceptance to develop the questionnaire.[49-56] Questions and methods were modified, with a focus on understanding the impact on hospital employees. The questionnaire consisted of 2 predemonstration and 3 postdemonstration sections. The first section included background questions. The second (predemonstration) and third (postdemonstration) sections provided matched questions on feelings about the VA. The fourth section included 2 unmatched questions about how the participant felt this technology would impact veterans and whether the VA should implement similar technologies. We used a 5-point Likert scale for sections 2, 3 and 4 (1 = not at all to 5 = extremely). Two unmatched free-text questions asked how the technology could be used in the participant's hospital service, and another open-ended question asked for any additional comments. To reduce potential reporting bias, 2 VA employees that did not work at VAPAHCS assisted with the survey distribution and collection.

VAPAHCS employees were contacted by email and intranet to participate in the demonstration and survey, which took place on February 10 and 11, 2020.

Data Analysis

All matching pre/post questions were analyzed together to determine statistically significant differences using the Wilcoxon signed rank matched pairs test and pooled *t* test. Survey respondents were also grouped by employment type to evaluate the impact on subgroups. Results were also grouped by VA tenure into 4 categorical 10-year increments (0-10, 11-20, 21-30, 31-40). Additionally, analysis of variance (ANOVA) was performed on employment types and VA tenure to understand whether there was a statistically significant difference in responses by these subgroups. Respondents' optional free-text answers were manually reviewed by 2 authors (ZPV and DMA), classified, coded by the common themes, and analyzed for comparison.

RESULTS

A total of 166 participants completed the predemonstration survey, which was a requirement for participating in the AR demonstration. Of those, 159 staff members (95.8%) also completed at least part of the postdemonstration paired structured questions, and their results were included in the analysis. On average, the participants had worked in health care for nearly 15 years, and at the VA for nearly 10 years; 86 respondents (54.1%) were women (Table 1).

Paired Questions

For questions about how innovative the VA is, 108 of 152 participants (71.1%) provided higher scores after the demonstration, 42 (27.6%) had no change, and 2 respondents (1.3%) provided decreased scores. The mean innovative score increased from 3.4 predemonstration to 4.5 postdemonstration on a Likert scale, which is a 1.1 point increase from predemonstration to postdemonstration (95% CI, 0.9-1.2) or a 22% increase (95% CI, 18%-24%) ($P < .001$). Respondents level of excitement about VA also increased with 82 of 157 participants (52.2%) providing higher scores after the demonstration, 71 (45.2%) had no change, and 4 scores (2.5%) decreased. The predemonstration mean excitement score

TABLE 1 Respondent Demographics (N = 159)

Characteristics	Results
Employment, mean (SD), y	
Health care	14.6 (10.8)
US Department of Veterans Affairs	9.6 (8.3)
Sex, No. (%)	
Female (%)	86 (54.1)
Male	73 (45.9)
Department, No. (%)	
Administration	44 (27.7)
Clinical	52 (32.7)
Support	21 (13.2)
Other	42 (26.4)
Veteran status, No. (%)	
Veteran	32 (20.1)
Nonveteran	113 (71.1)
No answer	14 (8.8)

TABLE 2 Change in Innovation Perception by Tenure

	Survey response			
Tenure	Predemonstration	Postdemonstration	Change	*P* value
0-10 y	3.2	4.3	+0.9 (18%)	< .001
11-20 y	3.7	4.6	+1.1 (22%)	< .001

Abbreviation: VA, US Department of Veterans Affairs.

of 3.7 increased to 4.3 postdemonstration, which is a 0.6 point increase from before to after the demonstration (95% CI, 0.5-0.7) or a 12% increase (95% CI, 10%-14%) ($P <$ .001). In the survey, 36 of 149 participants (24.2%) had higher scores for their expectation to continue working at VA postdemonstration, 109 (73.2%) had no change, and 4 scores (2.7%) decreased. The mean employee retention score increased from 4.2 predemonstration to 4.5 postdemonstration, which is a 0.3 point increase between pre-post (95% CI, 0.2-0.4) or a 6% increase (95% CI, 4%-8%) ($P <$ .001)

The pre/post questions were analyzed using 1-way ANOVA by hospital department and VA tenure. The responses by department were not statistically significant. Of the 159 employees assessed, 101 respondents (63.5%) had 0 to 10 years VA tenure, 44 (27.7%) had 11 to 20 years, 10 (6.3%) had 21 to 30 years, and 4 (2.5%) had > 31 to 40 years. Length of VA tenure did not impact respondent excitement. Respondents opinions on innovation in the 0 to 10 year and the 11 to 20 year groups rose from 3.2 and 3.7 predemonstration to 4.3 and 4.6 postdemonstration, respectively ($P <$ .001 for both statistical comparisons) (Table 2). Interestingly, the 0 to 10 group saw a 9% rise from a 4.0 score predemonstration to a 4.4 score postdemonstration ($P <$ .001), indicating that the demonstration had a positive impact on their plans to continue employment at VA (Table 3).

Sex did not play a significant role in how respondents answered questions regarding VA excitement or innovation. However, there was a statistically significant difference in how male and female respondents answered the predemonstration question about their plans to continue VA employment, according to the Wilcoxon rank sum test. Predemonstration, female respondents had a mean score of 4.1, which was 6% lower than the 4.4 score of male colleagues ($P =$ .04). Veteran status did have an impact on how respondents felt about VA innovation, and their plans to continue employment at VA. After the demonstration, veteran staff felt the VA was more innovative compared with nonveterans: 4.7 vs 4.4, respectively, a 6% difference ($P =$ .02) Similarly, for the continued VA employment question, veterans had a mean score of 4.8 vs 4.4 for nonveterans, an 8% difference ($P =$ .03) These results suggest that the demonstration had more of an impact on veteran employees vs nonveteran employees.

Unpaired questions

There were 2 structured unpaired postdemonstration questions. Respondents agreed that similar technology would impact veteran health care with mean (SD) of 4.6 (0.6) and a median score of 5 on a 5-point Likert scale. Respondents also agreed on the importance of implementing similar innovations with mean (SD) of 4.7 (0.5), and a median score of 5.

The survey asked how this technology could benefit their hospital service department and had 64 responses. Forty-six respondents saw applications for education or patient care/surgery. Other responses shared excitement about the technology and its potential to positively impact patient education. There were 37 responses to the open-ended question: 21 respondents expressed excitement for the technology, and 10 respondents reiterated that the demonstration would be of benefit to patient care/surgery and training.

TABLE 3 Change in the Likelihood of Continuing Employment at VA by Tenure and Sex

Criteria		Survey response Predemonstration	Postdemonstration	Change	*P* value
US Department of Veterans Affairs tenure	0-10 y	4.0	4.4	+0.4 (9%)	< .001
	11-20 y	4.6			< . 001
	Difference	0.6 (12%)			
Sex	Female	4.1	4.5	+0.4 (9%)	< .04
	Male	4.4	4.6	+0.2 (4%)	< .04
	Difference	0.3 (6%)			

DISCUSSION

Successful development, design, and deployment of any new health care tool depends on leveraging insights from the employees that will be using and supporting these systems. Correspondingly, understanding the impact that advanced technologies have on health care employees' satisfaction, morale, and retention is critical to our overall institutional strategy. Our findings show that a one-time experience with AR/MR technology elicited positive employee reactions. Of note, the survey revealed statistically significant improvements in staff's view of the VA, with the greatest positive impact for questions about innovation, followed by excitement to work at the VA, and likelihood to continue work at the VA. It is very disruptive and costly when health care employees leave, and improving employee satisfaction and morale is important for better patient care and patient satisfaction, which is priority for VAPAHCS leadership.[57-62]

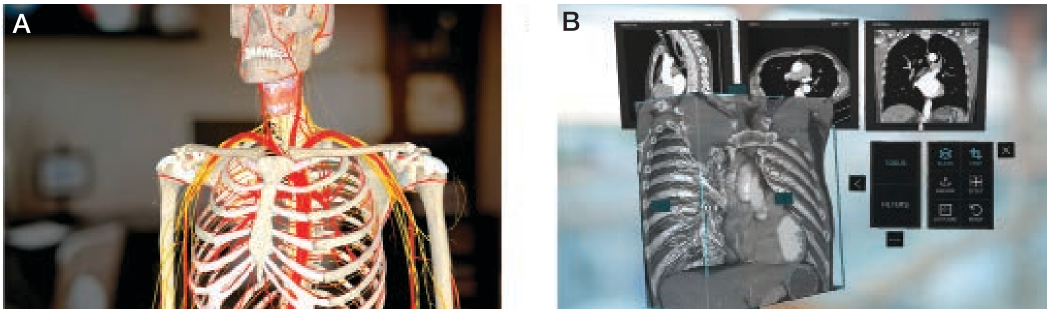
The paired predemonstration and postdemonstration scores were similarly high, nearing the top threshold available for the Likert scale (4.3 to 4.5). Furthermore, the least incremental improvement for these responses was observed for topics that had the highest initial baseline score. Therefore, the improvements observed for the paired questions may have more to do with the high baseline values.

Of additional interest, the self-reported likelihood of continuing to work at the VA increased the most for female employees, veteran employees, and employees with the least number of years at the VA. These demographic differences have important implications for VA staff recruitment and retention strategies.[62] The unpaired questions about the impact on veteran care and whether the VA should continue similar work demonstrated extremely high support with median scores of 5 for both questions. The free-text postdemonstration responses also demonstrate similar positive themes, with a disposition for excitement about both the training and patient care applications for this technology. In addition, respondents felt strongly that this and other similar technologies will positively impact the health care for veterans and that the VA should continue these efforts.

Strengths and Limitations

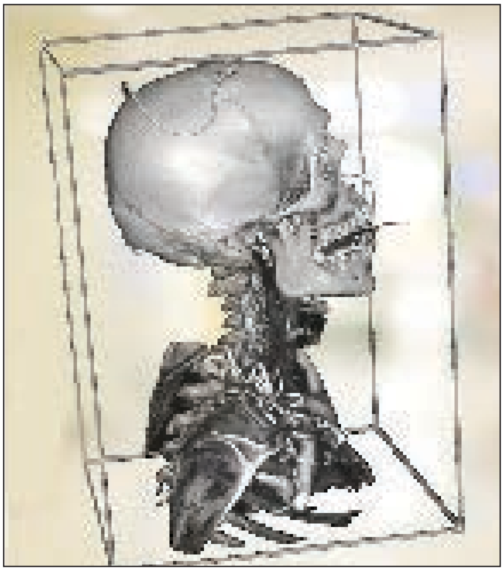
A strength of this assessment is the ability to evaluate survey responses that were systematically collected and matched from the same individual immediately before and after exposure to the new technology. The free-text responses provided additional important information that both confirmed the results and provided additional valued supplementary guidance for future implementation strategies, which is critical for our translational implementation goals. An additional strength is that the voluntary surveys were managed by non-VAPAHCS colleagues, limiting potential bias. Importantly, the number of respondents allowed a statistically significant assessment of important health care employee metrics. These results have emphasized how being part of an innovative organization, and the introduction of advanced AR/MR technol-

FIGURE 1 3D Holographic Mixed Reality Images



Abbreviations: 2D, 2-dimensional; 3D, 3-dimensional.
Examples of interactive 3D holographic renderings used for the demonstration. A, AnatomyX 3D hologram with the bone, connective tissue, artery, and neuro layers activated; B, SurgicalAR interactive 3D hologram in the foreground rendered from a patient's routine computed tomography scan with traditional 2D images in the background, as well as a control panel to the right, which were all accessible real-time through the mixed reality system.

FIGURE 2 3-Dimensional Holographic Model



ogy, improve employees' satisfaction and morale about where they work as well as their intention to stay at their institution.

A limitation of this assessment was the lack of comparative data for employee acceptance of other technologies at VAPAHCS. This limits our ability to differentiate whether the strong positive results observed in this evaluation were a result of the specific technology assessed, or of new and advanced health care technology in general. Nonetheless, our unpaired questions, which received extremely high scores, also included participant questions about comparing the system with other similar technologies. This assessment was also focused on veteran care, which limits generalizability.

CONCLUSIONS

One-time exposure to advanced AR technology for health care significantly increased employee morale as measured by excitement about working at the VA as well as employee intention to continue employment at the VA. These collateral benefits of the technology are particularly important in health care because our employees are our most important asset and improving employee morale equates to better patient care. Positive impacts were most pronounced for women employees, newer VA employees, and employees who are also veterans. These more detailed insights are also positioned to have a direct impact on employee recruitment and retention strategies. Additional valuable insights regarding the most applicable use of the technology in the clinical setting were also obtained.

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Disclaimer

The opinions expressed herein are those of the authors and do not necessarily reflect those of *Federal Practitioner,* Frontline Medical Communications Inc., the US Government, or any of its agencies.

Ethics and consent

This study was determined to be nonresearch by the Stanford University (Stanford, CA, USA), Institutional Review Board which is the Institutional Review Board for the US Department of Veterans Affairs, Palo Alto Health Care System. No identifiable information was collected.

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eAPPENDIX Scoping Review of Emerging Health Care Applications for Extended Reality Technologies Published in the Last 2 Years

Studies	Applications	Descriptions
Rawlins et al, 2021[6]	Inpatient pain, anxiety	VR reduced pain and anxiety for hospitalized patients.
Chawdhary et al, 2021[7]	Otology	Successful applications that used high-quality otoscopic imaging in diagnosis and segmentation for tinnitus, facial palsy, and Meniere disease.
Asadzadeh et al, 2021[8]	Inpatient infection control	VR was used more than AR in emergency management of infectious diseases; VR technology was used successfully by simulating pathogen structure, transmission, and human behavioral responses.
Ashwini et al, 2022[9]	Home health	Pulse oximeter AR application eliminated need for user product manual in home health settings.
Brooks, 2021[10]	Rehabilitation	Applications for therapeutic interventions: rehabilitation with movement tracking and feedback; VR training in early neurodevelopmental disability stages; VR for buoyancy rehabilitation training; and vibroacoustic intervention.
Koulouris et al, 2022[11]	Physical therapy	Prototype platform to promote exercise activities and monitoring physical and cognitive status used gamification techniques that combine AR, sensors, and mobile devices; it was validated in real-world scenarios, and results were analyzed to improve performance and usability.
Deiss et al, 2022[12]	Dermatology	Results of a prototype application for patients with inflammatory skin diseases and demonstrated AR visualizations of affected skin legions, their worsening, and prevention.
Bertino et al, 2022[13]	Dermatology	Application of AR technique to skin rashes and allergies attempted to resolve typical initial patient avoidance reaction for dermatology visit and possible deterioration due to delay.
Ruhaiyem and Mazlan, 2021[14]	Oncology, treatment planning	AR informed treatment localization for hepatocellular carcinoma.
Park et al, 2020[15]	Surgery - planning cardiovascular	Mobile application based on AR techniques for 3D heart images enabling interactive surgery planning; omnidirectional slicing and virtual annotation make this tool powerful during planning.
Leo et al, 2021[16]	Surgical,navigation	Feasibility study for the use of mixed reality in surgical navigation.
Zuo et al, 2020[17]	Surgery, spine	AR applications, successive enhancements, and future potential in spine surgery.
Ghaednia et al, 2021[18]	Surgery, spine	Systematic review of literature related to AR spine surgery applications that underscores developments in using technology in pedicle screw instrumentation.
Liu et al, 2022[19]	Nursing, patient monitoring	This study evaluates 3 prototype variants of an AR application to critical care nursing in the context of monitoring patients during transport.
Kimmel, Cobus, Heuten[20]	Psychiatry, treating phobia	Application of VR in the treatment of arachnophobia to streamline course of therapy and provide tool to tailor process according to specific patient requirements.
Multiple studies[21-29]	Teaching and training applications	Multiple papers discuss the merits of XR for teaching anatomy, life support, surgery, stroke awareness, hand hygiene, as well as others, including game applications in health care.

Abbreviations: 3D, 3-dimensional; AR, augmented reality; VR, virtual reality.