360° Operative Videos: A Randomised Cross-Over Study Evaluating Attentiveness and Information Retention

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OBJECTIVE: Although two-dimensional (2D) and three-dimensional videos have traditionally provided foundations for reviewing operative procedures, the recent 360º format may provide new dimensions to surgical education. This study sought to describe the production of a high quality 360º video for an index-operation (augmented with educational material), while evaluating for variances in attentiveness, information retention, and appraisal compared to 2D.

DESIGN: A 6-camera synchronised array (GoPro Omni, [California, United States]) was suspended inverted and recorded an elective laparoscopic cholecystectomy in 2016. A single-blinded randomised cross-over study was performed to evaluate this video in 360º vs 2D formats. Group A experienced the 360º video using Samsung (Suwon, South-Korea) GearVR virtual-reality headsets, followed by the 2D experience on a 75-inch television. Group B were reversed. Each video was probed at designated time points for engagement levels and task-unrelated images or thoughts. Alternating question banks were administered following each video experience. Feedback was obtained via a short survey at study completion.

SETTING: The New Academic and Education Building (NAEB) in Dublin, Royal College of Surgeons in Ireland, July 2017.

PARTICIPANTS: Preclinical undergraduate students from a medical university in Ireland.

RESULTS: Forty students participated with a mean age of 23.2 ± 4.5 years and equal sex involvement. The 360º video demonstrated significantly higher engagement ($p < 0.01$) throughout the experience and lower task-unrelated images or thoughts ($p < 0.01$). Significant variances in information retention between the 2 groups were absent ($p = 0.143$) but most (65%) reported the 360º video as their learning platform of choice. Mean appraisal levels for the 360º platform were positive with mean responses of >8/10 for the platform for learning, immersion, and entertainment.

CONCLUSIONS: This study describes the successful development and evaluation of a 360º operative video. This new video format demonstrated significant engagement and attentiveness benefits compared to traditional 2D formats. This requires further evaluation in the field of technology enhanced learning. (J Surg Ed 75:993-1000. © 2017 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Operative recording, 360° videos, resident training, virtual reality

COMPETENCIES: Medical Knowledge, Interpersonal and Communication Skills

INTRODUCTION

Although video-based teaching has complimented medical education for considerable time, it may occupy a more significant role in the near future. Global working time

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directives are restricting operative exposure among surgical residents.[1-3] The role of simulation is becoming established in resident training and we may be seeing a learning shift from active participation to passive observation, owing to financial and temporal restrictions.[4] In the current era, surgical educators lack confidence in the technical ability of their residents to operate independently.[5] The recent technological advances in virtual and augmented reality may have a role in compensating for diminished operative exposure.

Engaging the trainee audience remains challenging for most surgical educators as distractions can be detrimental to learning.[6] With significant staff and monetary resources invested into simulation and surgical education, trainers may not have adapted their teaching styles to befit the newer generation.[7] Perceptions among students are that e-learning technologies positively transform learning.[8] Although the 'digital division' between student and mentor is well described,[9,10] it may be widening with the recent pace of technological advances. In this digital age, the surgical technology used in every day operations may far outstrip the fidelity of simulation and learning used to underpin these techniques.

Surgical residents frequently rely on videos to reenact the operative steps and techniques in anticipation of future experiences. Typically, surgical e-learning was intricately tied with operative videos in 2-dimensional (2D) format, but 3-dimensional (3D) recordings are becoming available, which provide a more realistic illusion of depth.[11] Although current videos provide a focussed re-enactment of the operation, the viewpoint is limited and abstract owing to their inherent inability to manipulate the perspective.

With recent advancements in virtual reality and camera technology, 360º videos are slowly emerging in entertainment, where traditionally the novelty lay with 3D recordings. These videos provide visualization of the environment in all perspectives simultaneously, enabling users the observation as if immersed in the location. However, videos of operative material are scarcely available in this format owing to the technology's recent release.

This study sought to produce high quality, 360º didactic operative videos augmented with educational material, using consumer available technologies. The following single-blinded randomised cross-over study intended to assess the impact these 360° videos have on a student population. The primary aim of this study was to assess the variance in attentiveness levels in a 360° video compared to the traditional (2D) format. Secondarily, the study aimed to evaluate both video formats for variances in information retention and to achieve appraisals from the student population.

METHODS

Camera Hardware

A GoPro (California, United States) Omni (MHDHX-006) camera rig was inverted and suspended over the operating table during an elective laparoscopic cholecystectomy procedure in a tertiary teaching hospital. This camera rig incorporated 6 GoPro Hero4 Black edition cameras orientated in a synchronised cube array (Fig. 1). The array's synchronised hub allows the user simple configurations across all cameras and precise pixel level synchronisation.[12] The cameras recorded high-definition video (3:2 aspect ratio, 30 frames/s) onto 6 128 Gb memory cards. The camera mounting system utilized Phottix (Hong Kong, China) P-62 Variable pole and Kupo (NewYork, United States) 9-inch (23 cm) Super Viser Clamp in a vertical semirigid configuration. Simultaneously, a standard 2D High Definition Camcorder (Canon [Tokyo, Japan] XA10) recorded theater participants and the operative site in 1080p (progressive) resolution.

Video-Editing

The video content from the 6 GoPro Hero4 Black cameras was merged into a single equirectangular video (3840 × 1920 resolution) using Kolor (Francin, France) Video Pro and Giga software editions. This video was subsequently edited using Adobe (California, United States) Aftereffects and Mettle (Montreal, Canada) Skybox Studio Plugin

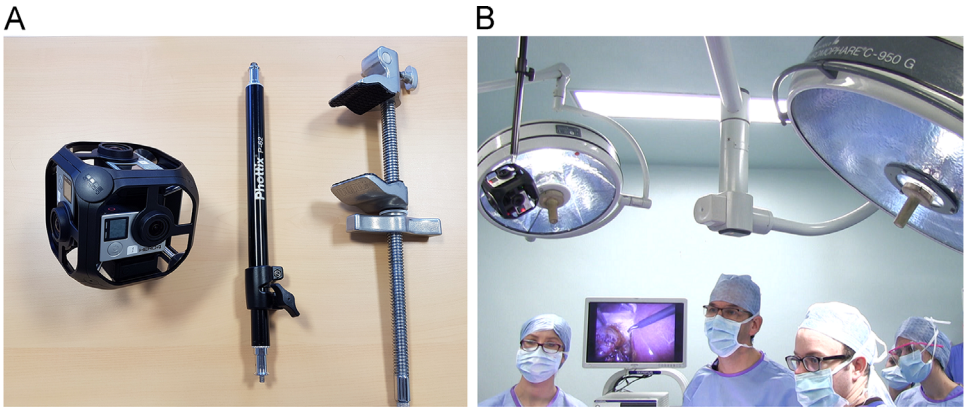

FIGURE 1. Hardware: (A) camera array and (B) theater configuration.

(version 2) on a desktop-computer (Microsoft [Washington, United States] Windows 10). The Mettle Skybox software provided authors the ability to input text, images, and the 2D video superimposed on the 360º video (Fig. 2).

The video was augmented with patient radiology (ultrasound and magnetic resonance cholangiopancreatography images), operative educational imaging, and an artificial 2D screen alternating between the laparoscopic camera and the 2D camera feed. The 2D camera feed provided close visualization of the surgeons and operative site while allowing adjustment of aperture for intense theater lighting. Both the 360º video and 2D screen were synchronised to match a given time period. Didactic audio accompanied the video describing anatomical structures and surgical technique.

Study Setting

This randomised single-blinded cross-over (2 × 2) study was conducted in June to July 2017 in the Dublin-based New Academic and Educational Building (NAEB) of the Royal College of Surgeons in Ireland (RCSI). Participants were consecutively enrolled from preclinical years of a medical university (Fig. 3). Any participants from clinical undergraduate years (≥fourth year) were excluded from the study. All participants voluntarily consented to participation.

The final operative video (10 min duration [supplementary]) was available for visualizing in equirectangular panorama (2D) format on a 75-in Sony LED television or 360° video format using Samsung (Suwon, South Korea) Gear-VR headsets (Fig. 4).

Participants were randomly assigned to group A or group B sequentially in a 1:1 ratio by recruitment number. Interventions and group assignment were coded and stored by authors (G.W.B and A.W.B). Remaining authors were blinded to assignments. Individuals in group A (maximum of 3 participants per session) experienced the 360° video initially followed by the 2D video. In group B the video order was reversed. Each video was probed by a visual stimulus at 4 time-periods of 3, 5, 7, and 9 minute durations and participants completed 2 questions relating to the presence of task-unrelated images or thoughts (TUIT) and subjective level of engagement at each time probe. This self-reported instrument evaluated participants for the frequency of mind wandering during their experiences. The frequency of TUIT was evaluated by the self-caught method[13] and involved participants recording (yes/no response) if they experienced a TUIT at each time probe. Demand characteristics are minimized with this technique as participant's daydreaming frequency is reported but thought content is not divulged.[14]

After each video, participants completed 1 of 2 standardised question banks (8-point multiple choice) related to the video content. The question content focused on applied surgical technique/anatomy and materials, knowledge unfamiliar to undergraduate preclinical students. These question banks were randomly distributed from a generated pool and evaluated among authors for overall complexity before being piloted on preliminary participants for feedback. At study completion, participants completed a 15-point questionnaire with a series of open/closed and Likert-scale questions related to demographics and their video experiences (360º vs 2D).

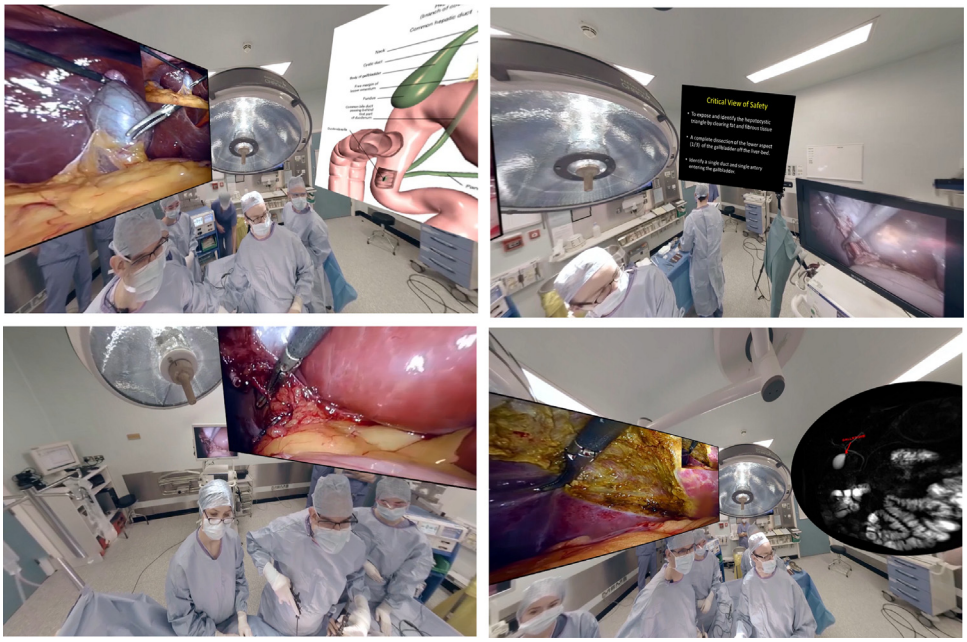

FIGURE 2. 360° video screenshots.

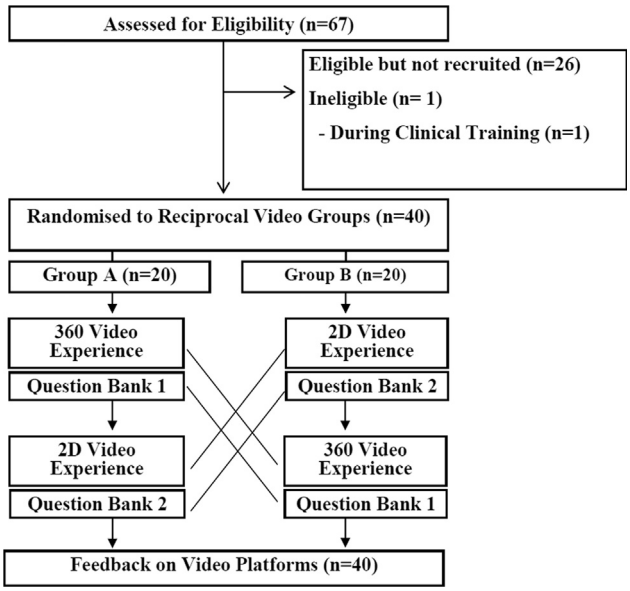

FIGURE 3. Participant flow.

The entire testing phase lasted in total 30 minutes per participant at a single sitting.

Statistical Analysis

Simple descriptive statistics are presented on engagement levels, TUIT responses and question banks for each video-platform at each time point. A mixed-effects analysis with participant as a random effect and platform and time-point as fixed effects was performed (crossover analysis). To ascertain a potential carryover effect, video-platform sequence was also included in the models. Statistical significance was determined at the 5% level. SAS Version 9.4 was used for data screening, management, and analysis. Feedback responses were converted to statements in a ternary plot using accumulated data with responses: 7 to 10 deemed agreeable, 4 to 6 as neutral, and 0 to 3 as disagreeing. Manual coding of free text comments was performed for open-ended survey responses. Ethical approval was granted for this study by the regional ethics committee (REC 1347b).

RESULTS

A total of 40 undergraduate students participated with 100% achieving study completion. One additional participant was excluded owing to occupying a clinical undergraduate stage. The mean age of responses was 23.2 ± 4.5 years with equal sex involvement (Table 1). Approximately 83% were undergraduate medical students, and 67.5% had not experienced 360° videos before.

Cross-over analysis revealed significantly higher engagement level with the 360º video platform ($p < 0.0001$) and across time periods ($p = 0.0007$) with no significant carryover effect ($p = 0.9722$). A significantly lower TUIT was determined overall for the 360º platform ($p < 0.0001$) and across time periods ($p = 0.0005$) with no significant carryover effect ($p = 1.000$).

Analyses of the video probes (Table 2) revealed that the 360° video demonstrated significantly higher ($p < 0.01$) engagement levels across all 4 time points and the significance became stronger as the video progressed ($p < 0.0001$ at 9 min). The analyses also revealed significantly higher ($p = 0.0021$) TUIT in the 2D video experience overall (estimated difference −0.60). On evaluation of information retention, there were no significant variances found in quiz performance between video formats (estimated difference = −0.55, $p = 0.1427$) and no carryover effect identified ($p = 0.2284$).

Almost two-thirds of participants reported choosing 360° videos as their platform of choice, whereas the remaining responders were divided between undecided and the 2D format (Table 1). A total of 95% of participants self-reported a level of engagement of at least 75% for the duration of the 360° video. The 360° video received favorable feedback from participants with most recommending the experience (mean score 8.7). Participants reported it as a beneficial platform of learning (mean 8.2), entertaining (mean 8.9), and immersive (mean 8.6) (Fig. 5).

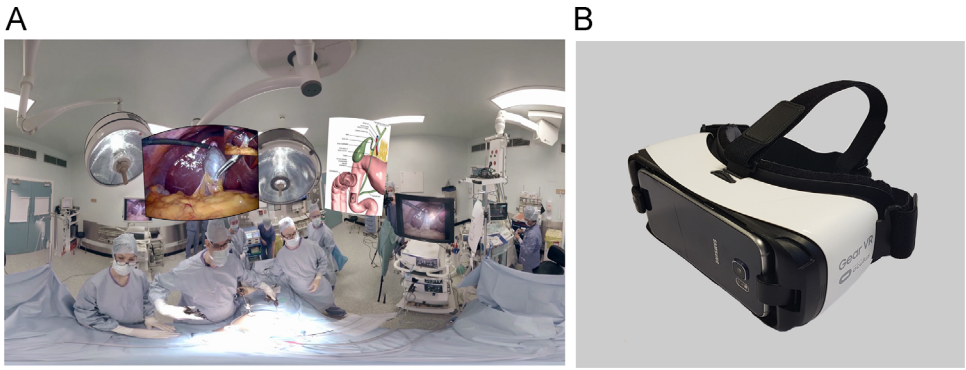

FIGURE 4. 360° and 2D video format experiences.

TABLE 1. Participant Demographics and 360° Video Feedback

Count	Variable	Total ($n = 40$)
1	Sex (female)	20 (50.0%)
2	Age	23.2 ± 4.5
3	Undergraduate year	1.7 ± 0.7
4	Undergraduate course	
	Medicine	33 (82.5)
	Physiotherapy	3 (7.5)
	Pharmacy	3 (7.5)
	Biomedical	1 (2.5)
5	History of 360° video use (yes)	13 (32.5)
6	Recommend 360° video	8.7 ± 2.1
7	Beneficial for learning	8.3 ± 1.7
8	Level of immersion in 360° video	8.6 ± 1.2
9	Entertainment value	8.9 ± 2.3
10	Preferable video platform	
	2D	7 (17.5)
	360°	26 (65.0)
	Unsure	7 (17.5)
11	360° engagement overall	
	100%	18 (45.0)
	75%	20 (50.0)
	50%	2 (5.0)
	25%	0 (0)
	0%	0 (0)
12	Benefit in augmented content	8.0 ± 2.3
13	Level of nausea	0.7 ± 1.6

n (%) for categorical data, mean ± SD for continuous.

Qualitative analyses of open participant comments for aspects of the 2 video platforms (360° vs 2D) revealed: engaging/immersive (50% vs 2.5%), interesting (7.5% vs 0%), easier to focus (2.5% vs 15%), retention benefits (2.5% vs 0%), content assimilation (2.5% vs 0%), interactivity (5% vs 0%), less distracting (2.5% vs 5%), simpler technology benefit (0% vs 7.5%), and less nausea (0% vs 2.5%).

DISCUSSION

This study has described the successful production and distribution of a 360º operative video to medically orientated students using consumer available technology. This 360º experience was successfully augmented with 2D video and educational imagery. The primary outcome of this study was to assess the variance in attentiveness between 360º and 2D video formats. This study demonstrated higher engagement and attentiveness (lower TUIT) associated with the 360° format. The secondary outcome was both to assess information retention and appraisal variances between the video platforms. Feedback from participants was positive, with overall responses perceiving the 360° experience as both entertaining and beneficial to learning. However, there were no significant variances determined for information retention.

Rather than an abstract viewing of a 2D video on a screen, the 360º platform provides participants a sense of immersion/presence in the environment (mean response 8.6) and to experience rather than observe the surroundings. This more active observation may heighten understanding and learning as theories such as Edgar Dale's Cone of Learning suggests.[15] With almost complete visual and auditory immersion, this engaging platform may overcome some of the many distractions impeding effective learning.[16] Participants perceived the 360° experience as engaging with almost two-thirds reported being at least 75% attentive during its entirety. Level of attentiveness with educational platforms is critical with mind-wandering negatively correlating with learning outcomes for both formal and video lectures.[17]

Video-based teaching has been demonstrated to be effective in a number of areas including the reinforcement of practical skills training and compliance with theater

TABLE 2. Video Platform Variances

Count	Variable		Video 360 ($n = 40$)	Video 2D ($n = 40$)	Estimated Difference (360-2D)*	p Value*
1	TUIT probe 1 (3 min)	No	38 (95.0)	33 (82.5)	−0.13	0.0997
		Yes	2 (5.0)	7 (17.5)		
2	TUIT probe 2 (5 min)	No	36 (90.0)	30 (75.0)	−0.15	0.0484
		Yes	4 (10.0)	10 (25.0)		
3	TUIT probe 3 (7 min)	No	32 (80.0)	27 (67.5)	−0.13	0.0997
		Yes	8 (20.0)	13 (32.5)		
4	TUIT probe 4 (9 min)	No	31 (77.5)	23 (57.5)	−0.20	0.0087
		Yes	9 (22.5)	17 (42.5)		
5	TUIT probe total		0.6 ± 1.1	1.2 ± 1.2	−0.60	0.0021
6	Immersion/engagement level probe 1 (3 min)		8.8 ± 1.3	7.9 ± 1.9	0.90	0.0025
7	Immersion/engagement level probe 2 (5 min)		8.7 ± 1.4	7.7 ± 1.6	0.93	0.0019
8	Immersion/engagement level probe 3 (7 min)		8.3 ± 1.6	7.2 ± 1.7	1.03	0.0006
9	Immersion/engagement level probe 4 (9 min)		8.3 ± 1.5	6.8 ± 2.1	1.50	<0.0001
10	Quiz performance		4.6 ± 1.6	5.1 ± 1.7	−0.55	0.1427

n (%) for categorical data, mean ± SD for continuous variables.
Cross-over analysis.

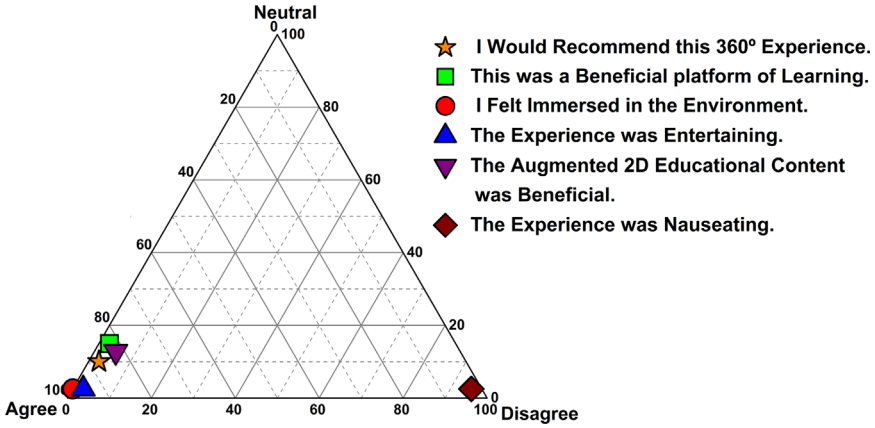

FIGURE 5. Ternary plot of feedback appraisals.

safety protocols.[18,19] Videos can increase medical-practitioners' comfort levels with specific procedures.[20] Traditionally, reviewing a surgical procedure and operating room was conveyed to residents in formal or distant learning using 2D or 3D video technologies. However, observing one-part in a well-oiled machine will not convey understanding to an apprentice. The 360º videos provide the whole picture to an audience. They provide valuable insights into the complex interpersonal interactions that occur with the entire theater team throughout an operative procedure. This may provide an array of opportunities to not only educate but also study human behavior and interactions in a stressful environment.

With increased pressures on optimum code-blue and trauma scenario training, 360º videos have the ability to capture these complex team-interactions between medical professionals, nurses, and ancillary staff. This may play a role as a learning tool in team building, communication skills development and responsiveness, to reinforce behaviors and increase patient safety. Aspects of team-training for virtual reality have been identified as useful developments in the future.[21,22] As it can be assessed retrospectively it may further occupy a role in formal-examinations and hospital-based audits.

Although being described as a 360º video platform, it is the authors' aspirations that the medical community appreciate it as a learning environment. As presented in this study, the platform allows an assimilation of multiple learning resources into the spherical environment and the augmentation of material with 2D/3D images, videos, animations, infographics, or relevant anatomy. It may provide an alternative model or stream for education to accompany current pedagogical approaches. By fully immersing users in virtual reality headsets it presents a collaboration of educational material in a single environment.

Despite the ever increasing fidelity and expense of simulator modalities and educational resources, research suggests that they are significantly underutilised by residents in a voluntary capacity. This may be owing to factors including lack of availability, level of enjoyment, and time commitments.[23,24] With working time restrictions in place across many nations, further emphasis on asynchronous lower-order learning in the home environment is essential.[25] We have described the relatively ease in delivering a 360º video to headset compatible devices. Although it would be optimistic to suggest virtual reality headsets can be found in most educators homes since their recent conception, the authors believe that it should be considered a viable platform for medical education and videos into the future.

As aptly described over a decade ago[26], "Today's students are no longer the people our educational system was designed to teach." We must adapt education methods to accommodate for these evolving and varying learning styles.[27]

Limitations

As a single center study, one must acknowledge the relatively small participant numbers may serve as bias. Survey questions were posed in 10-point bipolar scales with labeled explanations to reduce acquiescence bias. One must be conscious that this as well as the novelty factor of the new technology (67.5% of participants) may positively influence results.

Self-reported levels of nausea were low (0.7 out of 10) but varied substantially from 0 to 8 among participants suggesting a subjective component is involved. Virtual reality nausea is well described in the literature[28] and is owing to conflicts between the visual and vestibular senses. As the camera in this experience was stationary and contents were of low velocity, virtual reality-induced nausea was minimized.

As with any new technology the novelty and exclusivity tends to inflate the expense. The consumer available GoPro camera array and Adobe video software (Creative Cloud)

are approximately €5639.87 at current market value. This involved a single investment of €5399.99 for the camera array and an annual subscription of €239.88 for the video-editing software. The camera setup is relatively simplistic but additional staff-time involved in postproduction editing must be incorporated into anticipated costs. Editing time depends on the duration and complexity of the procedure but may require between 5 and 10 hours excluding rendering time. These processes may be shortened as the technology develops and adoption rates improve. With increased expenses relative to traditional video recordings, the cost-effectiveness of this new technology is open to debate.

This study was unable to ascertain retention benefits of one video format to another. This may have been owing to the retention questionnaires being technically orientated rather than observationally minded. Although alternating standardised question banks were implemented in each study sequence to reduce the carryover effect, the lack of consistent outcome measures across the 2 video interventions may have altered results.

Although the volume of 360º videos is likely to increase, further study into the potential information retention of the platform is required. As both engaging and immersive, this novel video platform delivers significant e-benefits to audiences and may appeal to modern learning styles. The 360º videos may add a new dimension to education including orientations to new environments, team training, and formal-examinations across multiple disciplines. Rather than solely the technical nuances of operations, the applications of these videos may prosper with more junior medical personnel or students as an aid to theater induction and protocols for safe practices. These provide a re-enactment of the simulated environment without risk of contamination by untrained personnel. They may supplement the traditional and often abstract experiences that occur for untrained observers in the theater environment.

Owing to the recent release of 360° videos, the learning curve associated with any new technology must be appreciated and niche educational applications of these videos may become more apparent over time. Higher fidelity virtual reality (3D 360º) videos are in development which provides 3D depth in all dimensions. These 3D 360° camera arrays such as the GoPro Odyssey may add further perspective but are significantly more expensive.[29]

CONCLUSION

This study has described the successful development and evaluation of an educationally augmented 360° operative video. This new video format demonstrated improved attentiveness and engagement amongst participants. It is the authors′ aspirations that this study provides a foundation for further developments on this video platform.

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SUPPLEMENTARY MATERIAL

Supplementary data are available in the online version of this article at http://dx.doi.org/10.1016/j.jsurg.2017.10.010