International Journal of E-Health and Medical Communications

April-June 2011, Vol. 2, No. 2

Table of Contents

Research Articles

Research Essay

Design Considerations for Delivering E-Learning to Surgical Trainees

Jane Coughlan, Brunel University, UK

Willem-Paul Brinkman, Delft University of Technology, The Netherlands

ABSTRACT

Challenges remain in leveraging e-health technologies for continuous medical education/professional development. This study examines the interface design and learning process features related to the use of multimedia in providing effective support for the knowledge and practice of surgical skills. Twenty-one surgical trainees evaluated surgical content on a CD-ROM format based on 14 interface design and 11 learning process features using a questionnaire adapted from an established tool created to assess educational multimedia. Significant Spearman's correlations were found for seven of the 14 interface design features – 'Navigation', 'Learning demands', 'Videos', 'Media integration', 'Level of material', 'Information presentation' and 'Overall functionality', explaining ratings of the learning process. The interplay of interface design and learning process features of educational multimedia highlight key design considerations in e-learning. An understanding of these features is relevant to the delivery of surgical training, reflecting the current state of the art in transferring static CD-ROM content to the dynamic web or creating CD/web hybrid models of education.

Keywords: *E-Health, Internet, Multimedia, Surgery, Training, Web-Based Learning*

1. INTRODUCTION

Multimedia applications have proven popular options in delivering education where the integration of different forms of media offer a structured approach to understanding the procedural tasks and decision points in practicing surgery (Luker, Sullivan, Peyre, Sherman, & Grunwald, 2008). Whilst evidence suggests that e-learning, for example in the form of interactive CD-ROMs can benefit surgical education (Baskin et al., 2008), the challenges in delivering this specialised learning material in an electronic format at both the undergraduate level and for continuous medical education/professional development remain (Cosman, Hemli, Ellis, & Hugh, 2007; Gold, Verrier, Olinger, & Orringer, 2002). E-learning comprises of two dimensions - interface design and learning that present specific challenges for delivering training. In terms of interface design, a key challenge in creating educational software is in presenting the appropriate scope and level of material that will engage learners without

DOI: 10.4018/jehmc.2011040102

distracting their attention from the relevant items of training information (Ardito et al., 2006; Spires & Preece, 1999). With respect to learning, a key challenge is in the provision of high fidelity demonstrations of surgical procedures and equipment use to allow purposeful practice of surgical skills and attain some degree of feedback on performance for the different types of surgical learning tasks (Khan, Widdowson, & Tiernan, 2004).

Effective educational software seeks to integrate different multimedia formats such as video clips, graphics, animations and audio to provide an interactive and engaging learning experience. However, it has been long been established that poor usability of educational software can be detrimental to learning performance (Megali, Tonet, Dario, Vascellari, & Marcacci, 2005; Parlangeli, Marchigiani, & Bagnara, 1999). Difficulties in learning surgical techniques through multimedia training can arise not because of the learning material itself, but because of inappropriate media formats. For example, a simple animation of the way a surgical tool is used might be more effective than an actual video clip. But a video clip could provide more contextual and realistic detail about a surgical tool compared to graphics, animation or photographs. Design issues have therefore been related to the appropriate selection and organisation of multimedia so that they do not cognitively overload learners (Grunwald & Corsbie-Massay, 2006). However, evaluations of these multimedia training applications are limited, particularly within the surgical training domain, where existing design guidelines do not necessarily accommodate even basic surgical learning demands (Haluck, 2005).

Evaluations of multimedia training are important in understanding the design considerations particularly within the context of surgical education where the growth of the Internet promises increasingly multimedia rich programs (Larvin, 2009; Rissucci et al., 2008). CD-ROMs are being converted to a web-based format or delivered using CD/Web hybrid products (Gold, Begg, Fullerton, & Mathiesen, 2004) and Web 2.0 technologies have facilitated the sharing of educational content (Boulos & Wheeler, 2007), particularly in the use of wikis such as WikiSurgery (www.wikisurgery.com) (Agha, 2006). Given that research has shown that multimedia based surgical training can be flexible enough to adapt to the individual needs of the user with different levels of experience and associated demands for learning (Friedl et al., 2006), it is important to understand the features that support this mode of learning in order to optimise the use of surgical teaching software and inform the development of new computer-assisted curricula. This study uses a multimedia interactive training CD-ROM as a case to examine the interface design and learning process features and their interrelationships and in so doing overcomes many of the problems associated with web-based delivery of education such as bandwidth limitations, loading delays and video streaming in restricted sites.

2. METHODS

This study sought to understand the interface design and learning process features of multimedia surgical training with the use of a CD-ROM titled: "PrimeSkills in Surgery" (Edwards, 1999). The CD-ROM is a relevant exemplar to study as it represents the following: (1) supporting material for trainees on a basic surgery skills training course in the UK; and (2) contribution to the current state of the art in converting CD-ROM content to a web-based format on the site: WikiSurgery (www.wikisurgery.com). The training provided by the CD-ROM enables the learner to: reflect on aptitudes and characteristics that may shape learning profiles; visualise demonstrations of surgical equipment and techniques of their usage; and process learning material by completing recall sections, surgical tests, exercises and quizzes to self-evaluate progress.

An evaluation tool was developed for use in this study, which was adapted from user interface features proposed by Reeves and Harmon (1994) and pedagogical features by Reeves (1998) for evaluating instructional

multimedia applications. This tool focuses on general multimedia evaluation and employs critical dimensions for evaluating computer-based instructional interfaces. It was selected for use in this study as recent work found that no specific tools for evaluating surgical multimedia exist (Coughlan & Morar, 2008). The tool adapted from Reeves and Harmon (1994, 1998) was validated for use in eliciting feedback on surgical multimedia training through consultations with experts in surgery, usability and education and was pilot-tested with a small group of trainees (n=6). This resulted in refinement of the tool so that it was fit for purpose to narrow down and focus on the core aspects under evaluation by the trainees.

Thus, key adaptations of the tool involved: decomposing the 'Screen design' design feature so that the trainees could evaluate the separate elements such as text, graphics, video, sound and speech; relabeling dimensions as features to make them more understandable (e.g., 'Cognitive load' was renamed 'Learning demands' under interface design; removing pedagogical dimensions such as 'Epistemology', which would have onerously required the trainees to make theoretical judgments on content; providing clear and concise definitions in layman's terms of each feature, which can be seen in Table 2 (e.g., 'Experiential value' was defined as: "The CD-ROM provides relevant experience; the response scale was changed to a five-point Likert scale for ease of rating and analysis; and additional background information on the participants, such as personal details, surgical experience and computer experience was collected.

The questionnaire was distributed to 48 surgical trainees who attended sessions of a basic surgical skills course in a specialist centre in the UK and who received the CD-ROM as part of their training. Of the 48 questionnaires distributed, 21 participants successfully completed and returned the questionnaire. This represents a percentage return rate of 43.8%, which is acceptable within published response rates of surveys with surgeons (Leece et al., 2004). The sample size of 21 participants is comparable to other interface evaluation studies of educational software (Kim, Brock, Orkand, & Astion, 2001) and greater than other surgical multimedia evaluation studies, where the sample size has been as low as 10 participants (Luker et al., 2008; Seixas-Mikelus et al., 2010).

3. RESULTS

Fourteen interface design features of the CD-ROM were rated on a 5-point Likert scale (Table 1) on average between 2.75 for 'Aesthetics' and 3.90 for 'Level of material' (where 1 = needs major improvement; 2 = needs minor improvement; 3 = fair; 4 = good; 5 = works excellently). One-sample t-tests[1] indicated that all averages were significantly above a rating of 2 — 'needs minor improvement'. The responses to the open-ended questions were also consistent with a positive rating for the software, revealing comments such as: *"I have been working in surgery for 1.5 years. This CD answered a lot of questions that I couldn't find answers to and gave me more confidence"*.

Eleven learning process features of the CD-ROM were rated on a 5-point Likert scale (Table 2) on average between 3.29 for 'Cooperative learning' to 3.85 for 'User activity' on a scale of strong disagreement (rating = 1) to strong agreement (rating = 5) with the feature's accompanying statement.

The results of one-sample t-tests indicate that the average rating of eight of the learning process features tended towards the positive agreement side of the rating scale and were significantly above a rating of 3. The features: 'Experiential value', 'Value of error', 'Cooperative learning', and 'Cultural sensitivity', however, did not reach a significant 0.05 level. For 'Experiential value' trainees seemed less positive. The perceived relevance of the material might have caused this. For example, one trainee commented that the CD-ROM *"for general surgery it is excellent; I am an orthopaedic surgeon therefore it has less relevance"*, and another trainee mentioned that *"I'm not sure a CD-ROM can provide relevant surgical experience, but it does cover relevant procedures in theory"*.

Table 1. Rating of interface design features and results of one-sample t-test with 2 as test value

Features	*n*	*Mean*	*SD*	*t*	*p.*
EASE OF USE User-friendliness	21	3.00	1.05	4.37	<0.01
NAVIGATION Ability to move through the contents and knowing how to get to different parts	21	3.19	1.25	4.37	<0.01
LEARNING DEMANDS Ability to recognise and understand the choices presented	19	3.74	1.05	7.24	<0.01
MAPPING Relationship between the choices, user actions on those choices and its corresponding outcome	19	3.47	0.77	8.32	<0.01
TEXT (e.g., instructions, descriptions)	21	3.10	1.34	3.75	<0.01
GRAPHICS (e.g., photos, diagrams, images, video stills)	21	3.43	1.29	5.09	<0.01
VIDEOS (e.g., video clips and animations)	21	3.29	1.27	4.64	<0.01
SOUND (e.g., music, artificially generated sound recordings)	19	3.16	1.12	4.51	<0.01
SPEECH (e.g., pre-recorded voices)	19	3.53	1.02	6.52	<0.01
MEDIA INTEGRATION Combination of different media (e.g., text, graphics, videos, sound and speech) into an effective whole	21	3.71	1.01	7.80	<0.01
LEVEL OF MATERIAL Presentation of the appropriate scope and level of detail of material	21	3.90	1.04	8.36	<0.01
INFORMATION PRESENTATION Ability to understand and learn from the way information is presented	21	3.81	1.08	7.69	<0.01
AESTHETICS Look and feel	20	2.75	1.16	2.88	0.01
OVERALL FUNCTIONALITY Perception of usefulness in meeting learning goals and objectives	21	3.43	1.08	6.09	<0.01

The perceived relevance of the 'Value of error' feature might have posed a problem for some trainees as it refers to the ability to learn from mistakes. For example, a trainee commented that *"it would be good if there were more interactive bits where you could test yourself"*. Trainees did not provide comments to explain the low rating for 'Cooperative learning'. The relatively large standard deviation for the 'Cultural sensitivity' feature indicates that trainees' opinion on this item greatly varied. However, this variation could not be explained by the nationality of the participants. An independent samples *t*-test with a grouping variable indicating whether a participant was British or non-British found no significant difference for these two groups on the 'Cultural sensitivity' rating ($t(12) = 1.11, p. = .29$). Still one non-British participant mentioned that the voices were clear *"but some discomfort in adjusting to different accents"*.

The second part of the analysis involved an examination of how the ratings of the interface design features related positively to the ratings of the learning process, as this would give

Table 2. Rating of learning process features and results of one-sample t-test with 3 as test value

Features	*n*	*Mean*	*SD*	*t*	*p.*	α if item deleted
GOAL ORIENTATION The CD-ROM focuses on its learning goals and objectives	21	3.76	1.04	3.34	<0.01	0.56
EXPERIENTIAL VALUE The CD-ROM provides relevant experience	21	3.48	1.08	2.02	0.06	0.55
TEACHER ROLE The CD-ROM facilitates the teacher's role	20	3.55	0.94	2.60	0.02	0.60
FLEXIBILITY The CD-ROM is modifiable by the teacher	13	3.77	0.73	3.83	<0.01	0.92
VALUE OF ERROR The CD-ROM allows you to make mistakes and learn from the experience	21	3.43	1.12	1.75	0.10	0.65
ORIGIN OF MOTIVATION The CD-ROM is intrinsically motivating	21	3.52	1.08	2.23	<0.01	0.52
INDIVIDUAL DIFFERENCES The CD-ROM accommodates a wide range of learners' individual differences	20	3.50	0.76	2.94	0.01	0.66
LEARNER CONTROL The CD-ROM allows unrestricted learner control over the material presented	21	3.57	1.12	2.34	0.03	0.63
USER ACTIVITY The CD-ROM creates an interactive learning experience	20	3.85	0.88	4.34	<0.01	0.64
COOPERATIVE LEARNING The CD-ROM provides support that is integral to group learning	21	3.29	0.96	1.37	0.19	0.56
CULTURAL SENSITIVITY The CD-ROM provides support that is integral to the cultural diversity of learners	15	3.40	1.18	1.31	0.21	0.67

insights into how evaluation of the *form*, e.g., multimedia design, relates to evaluation of the *content*, e.g., the learning of surgical skills. To reduce the complexity of the analysis, the ratings of the learning process features (Table 2) were reduced to a single index score for each trainee, hereafter referred to as the Learning Process Index (LPI). First, the internal consistency of the learning process features was inspected by calculating Cronbach's alpha, which is based on the average correlation of features. With all features included, alpha was 0.65, which is below the 0.7-0.8 recommended reliability threshold level (Loewenthal, 2001). In addition, Cronbach's alpha was calculated if an item was not included. As Table 2 shows removing the 'Flexibility' item allowed an acceptable alpha of 0.92. Presumably, this item was less related to the other features as it looks at the CD-ROM from an educators' point of view, whereas the other features take a learners' perspective. For each trainee, a single index score was calculated by summing all his or her rating of the features, excluding the 'Flexibility' feature. The resulting LPI was correlated with the scores of each interface design feature as displayed in Table 1 and the results of which are presented in Table 3.

Table 3. Spearman's correlation between interface design features and the Learning Process Index

Interface design feature	Correlation
Ease of Use	0.37
Navigation	0.60**
Learning Demands	0.84**
Mapping	0.22
Text	0.25
Graphics	0.28
Videos	0.54*
Sound	0.35
Speech	0.27
Media Integration	0.50*
Level of Material	0.66**
Information Presentation	0.58**
Aesthetics	0.21
Overall Functionality	0.77**

*p. <0.05; **p. < 0.01

The analysis revealed seven significant Spearman's correlations between the trainees' LPI scores and their rating of the interface design features, which are discussed using trainees' comments verbatim as follows:

1. **Navigation:** Trainees who rated both the LPI and navigation as relatively high wrote down as a positive aspect of the CD-ROM that it was *"easy to use - easy to move between screens and video clips load quietly."* In contrast, a trainee who rated the navigation and learning process relatively low mentioned that moving from one chapter to the other was difficult.
2. **Learning Demands:** The 'Learning demands' feature was both a supportive and limiting feature of the perceived learning process. For example, participants who scored both low on the feature and the LPI mentioned the linearity, or the lack of choice in the CD-ROM, as a negative aspect.
3. **Videos/Media Integration/Information Presentation:** Another consistent link between the interface design and learning process features was the way in which the learning material was presented, as indicated by significant correlations with 'Videos', 'Media integration' and 'Information presentation' features. The positive and negative aspects of the CD-ROM identified by the trainees support this finding. Trainees who marked low ratings on these interface design features and the LPI, mentioned as a negative aspect that some procedures were not clearly visible on the screen, such as the hands of the surgeon or the white suture, or they stated that the CD-ROM did not make use of the best interactive videos and sound technologies. On the other hand, trainees who rated these features highly, mentioned as positive the good use of multimedia, the clear and easy presentation and good quality of media (e.g., graphics, voiceovers, and videos), and also that they could actually watch how the procedures were performed.
4. **Level of Material:** The ratings of the appropriateness of the level and scope

of the material seem also to relate to the trainees' perception of learning support. For example, trainees who rated relatively high on both the 'Level of material' feature and the LPI, provided positive comments that related to aspects of the content of the CD-ROM such as relevance, thorough explanation, and a good balance between theoretical knowledge and practical procedures. In contrast, trainees who rated this feature low and the LPI wrote down as a negative aspect comments relating to the content such as *"there was too much detail on very basic concepts"*.

5. **Overall Functionality:** The significant correlation between the LPI and 'Overall functionality' seems to confirm that the quality of the interface design is related to the extent trainees found the CD-ROM to support their learning. The 'Overall functionality' item referred to the CD-ROM's usefulness in meeting learning goals and objectives. Again, participants on the high end of the scores mentioned usefulness of the exercises to practice, entertainment elements and motivational aspects of the CD-ROM; whereas trainees on the low end of the scores indicated the limited usefulness for people who had already completed their surgical skills course.

4. DISCUSSION

This study focused on understanding the interface design and learning features and the interplay between them that might contribute towards effective e-learning in surgery. The main observation of this study is the relation between form and content, in other words, how trainees' evaluation of the design of the software, relates positively to their evaluation of the potential learning support offered by the software. This therefore suggests that the design of educational multimedia is critical; otherwise trainees might be less motivated in using a program if it is not perceived to support learning. Computer-assisted learning through CD-ROMs, Internet and Web 2.0 technology represents the future for surgical education from an undergraduate level through to supporting continuing medical education and professional development and is an integral part of an e-health agenda. However, understanding the ways that surgeons learn and the key design elements that can be incorporated into multimedia applications to support the process is somewhat limited (Cochran, Edelman, Morris, & Saffle, 2008). Few evaluations of surgical training multimedia, specifically in terms of the relationship between usability and learning, have been undertaken despite the huge number of CD-ROM titles published and the

Table 4. Design considerations for surgical e-learning

Interface design feature	Design consideration
Navigation	Facilitate task-focused navigation to guide the trainee through the content with the additional use of feedback in response to a learning task
Learning Demands	Support interactivity so that the trainee can control access to the content with the additional use of appropriate links
Videos	Create realistic representations of real world exemplars that increase self-directed learning
Media Integration	Supply multiple channels to provide learning by observation as an apprentice experience
Level of Material	Deliver content that can be personalised to the skill and knowledge level of the trainee
Information Presentation	Generate clear visualization of the content and its structure, available options and the recognition of errors
Overall Functionality	Provide authentic learning environments that include motivating tasks to help retain the attention of the trainee

increasing move towards developing CD/Web hybrid curricula (Cook, 2009).

In this study trainees, overall, were positive towards the CD-ROM as a format that can deliver learning. Thus, the main conclusions of the study can be framed as a set of design considerations for surgical e-learning. These are drawn from the preceding analysis and are based on the significant Spearman's correlations and are akin to a set of 'learning with software' heuristics (Spires & Preece, 1999) that adds to previous work seeking to establish criteria for multimedia training tools (Ardito et al., 2006; Grunwald & Corsbie-Massay, 2006; Herrington, 2006; Huang, 2005). Web-based technologies can fully exploit the use of multimedia, but implementation issues exist, which can be framed according to lessons learned for specific design considerations displayed in Table 4.

The approach taken in this work focused on the evaluation of educational software for surgical trainees with a view to addressing usability and learning issues as captured by the LPI scores and ratings of the interface design features. The validity of the design considerations as a set of heuristics for predicting the effectiveness (software to learn from) and efficiency (learning from software) of surgical training, prompts future work in three main ways. Firstly, the study has put forward a set of design considerations that are in their infancy, but which could be used as heuristics to evaluate surgical multimedia and refine and develop our understanding of delivering specialised learning material for medical education. Secondly, there is a need to relate key pedagogical principles in learning theory such as split attention, learner control and cognitive overload (Clark & Mayer, 2003) to the design considerations to generate deeper insights on the critical aspects of learning that can help or hinder designers/educators in developing surgical e-learning programs. Thirdly, investigating the way in, and extent to, which trainee characteristics (e.g., learning styles) have an effect on the learning process and associated design of the educational software that can support trainees' individual/group learning needs whilst 'outside the theatre' to achieve the competence levels required to practice surgery.

REFERENCES

Agha, R. (2006). Introducing Wikisurgery.com: The blueprint for a surgical architecture of participation. *International Journal of Surgery*, *4*(3), 140–143. doi:10.1016/j.ijsu.2006.07.002

Ardito, C., Costabile, M. F., De Marsico, M., Lanzilotti, R., Levialdi, S., & Roselli, T. (2006). An approach to usability evaluation of e-learning applications. *Universal Access Information Society*, *4*(3), 270–283. doi:10.1007/s10209-005-0008-6

Baskin, C., Seetharamu, N., Mazure, B., Vassallo, L., Steinberg, H., & Kerpen, H. (2008). Effect of CD-ROM-based educational intervention on resident knowledge and adherence to deep venous thrombosis prophylaxis guidelines. *Journal of Hospital Medicine*, *3*(1), 42–47. doi:10.1002/jhm.266

Boulos, M., & Wheeler, S. (2007). The emerging Web 2.0 social software: An enabling suite of sociable technologies in health and health care education. *Health Information and Libraries Journal*, *24*(1), 2–23. doi:10.1111/j.1471-1842.2007.00701.x

Clark, R. C., & Mayer, R. E. (2003). *E-learning and the science of instruction*. San Francisco, CA: Jossey Bass.

Cochran, A., Edelman, L., Morris, S., & Saffle, J. (2008). Learner satisfaction with web-based learning as an adjunct to clinical experience in burn surgery. *Journal of Burn Care & Research; Official Publication of the American Burn Association*, *29*(1), 222–226.

Cook, D. A. (2009). The failure of e-learning research to inform educational practice, and what we can do about it. *Medical Teacher*, *31*(2), 158–162. doi:10.1080/01421590802691393

Cosman, P., Hemli, J., Ellis, A., & Hugh, T. (2007). Learning the surgical craft: A review of skills training options. *ANZ Journal of Surgery*, *77*(10), 838–845. doi:10.1111/j.1445-2197.2007.04254.x

Coughlan, J., & Morar, S. (2008). Development of a tool for evaluating multimedia for surgical education. *The Journal of Surgical Research*, *149*(1), 94–100. doi:10.1016/j.jss.2007.09.015

Edwards, M. (1999). *Prime skills in surgery: Scalpel information systems*. Retrieved from http://wikisurgery.com/index.php?title=Michael_Edwards

Friedl, R., Hoppler, H., Ecard, K., Scholz, W., Hannekum, A., & Stracke, S. (2006). Development and prospective evaluation of a multimedia teaching course on aortic valve replacement. *The Thoracic and Cardiovascular Surgeon*, *54*(1), 1–9. doi:10.1055/s-2005-865871

Gold, J., Begg, W., Fullerton, D., & Mathiesen, D. (2004). Successful implementation of a novel internet hybrid surgery curriculum. *Annals of Surgery*, *240*(3), 499–509. doi:10.1097/01.sla.0000137139.63446.35

Gold, J., Verrier, E., Olinger, G., & Orringer, M. (2002). Development of a CD-ROM Internet hybrid: A new thoracid suregery curriculum. *The Annals of Thoracic Surgery*, *74*(5), 1741–1746. doi:10.1016/S0003-4975(02)04021-3

Grunwald, T., & Corsbie-Massay, C. (2006). Guidelines for cognitively efficient multimedia learning tools: Educational strategies, cognitive load, and interface design. *Academic Medicine*, *81*(3), 213–223. doi:10.1097/00001888-200603000-00003

Haluck, R. S. (2005). Design considerations for surgical based simulators. *Minimally Invasive Therapy*, *14*(4-5), 235–243. doi:10.1080/13645700500244222

Herrington, J. (2006, October 13-17). *Authentic e-learning in higher education: Design principles for authentic learning environments and tasks.* Paper presented at the World Conference on E-learning in Corporate, Government, Healthcare, and Higher Education, Honolulu, HI.

Huang, C. (2005). Designing high-quality interactive multimedia learning modules. *Computerized Medical Imaging and Graphics*, *29*(2-3), 223–233. doi:10.1016/j.compmedimag.2004.09.017

Khan, M. S., Widdowson, D., & Tiernan, E. (2004). The increasing significance of how to learn motor skills. *International Journal of Surgery*, *2*(2), 124–125. doi:10.1016/S1743-9191(06)60068-X

Kim, S., Brock, D., Orkand, A., & Astion, M. (2001). Design implications from a usability study of Gram Stain-Tutor. *British Journal of Educational Technology*, *32*(5), 595–605. doi:10.1111/1467-8535.00228

Larvin, M. (2009). E-learning in surgical education and training. *ANZ Journal of Surgery*, *79*(3), 133–137. doi:10.1111/j.1445-2197.2008.04828.x

Leece, P., Bhandari, M., Sprague, S., Swiontkowski, M., Schemitsch, E., & Tornetta, P. (2004). Internet versus mailed questionnaires: A controlled comparison. *Journal of Medical Internet Research*, *6*(4), 85–93.

Loewenthal, K. M. (2001). *An introduction to psychological tests and scales*. New York, NY: Psychology Press.

Luker, K. R., Sullivan, M. E., Peyre, S. E., Sherman, R., & Grunwald, T. (2008). The use of cognitive task analysis-based multimedia program to teach surgical decision making in flexor tendon repair. *American Journal of Surgery*, *195*(1), 11–15. doi:10.1016/j.amjsurg.2007.08.052

Megali, G., Tonet, O., Dario, P., Vascellari, A., & Marcacci, M. (2005). Computer-assisted training system for knee arthroscopy. *International Journal of Medical Robotics and Computer Assisted Surgery*, *1*(3), 57–66. doi:10.1002/rcs.28

Parlangeli, O., Marchigiani, E., & Bagnara, S. (1999). Multimedia systems in distance education: Effects of usability on learning. *Interacting with Computers*, *12*(1), 37–49. doi:10.1016/S0953-5438(98)00054-X

Reeves, T. C. (1998). *Evaluating what really matters in computer-based education*. Retrieved from http://www.eduworks.com/Documents/Workshops/EdMedia1998/docs/reeves.html

Reeves, T. C., & Harmon, S. W. (1994). Systematic evaluation procedures for interactive multimedia for education and training. In Reisman, S. (Ed.), *Multimedia computing - preparing for the 21st century* (pp. 472–505). Hershey, PA: IGI Global.

Rissucci, D., Numann, P., Welling, R., Pfingsten, M., Blair, P., & Sachdeva, A. (2008). Reactions of surgical program directors to a web-based interactive educational program focusing on cognitive skills. *Journal of Surgical Education*, *65*(6), 470–475. doi:10.1016/j.jsurg.2008.05.014

Seixas-Mikelus, S., Adal, A., Kesavadas, T., Baheti, A., Srimathveeravalli, G., & Hussain, A. (2010). Can image-based virtual reality help teach anatomy. *Journal of Endourology*, *24*(4), 629–634. doi:10.1089/end.2009.0556

Spires, D., & Preece, J. (1999). Predicting quality in educational software: Evaluating for learning, usability and the synergy between them. *Interacting with Computers*, *11*(5), 467–483. doi:10.1016/S0953-5438(98)00063-0

ENDNOTE

1 Each one-sample (2-tailed) *t*-test tested whether trainees' rating of a specific feature deviated on average significantly from a value 2 score on the answers scale. Note that one-sample *t*-tests were used because each time the average of a single sample obtained from the trainees is compared with a constant value. The degrees of freedom used in each test were *n*-1.

Jane Coughlan is a Lecturer in the Department of Information Systems and Computing at Brunel University. She received a BA (Hons) degree in Psychology, and a Master of Research both from Manchester University. Her interests lie in the design and usability of electronic environments. The focus of Dr Coughlan's research has been on investigating user behavior with technology and the nature of the user-system communication that influences interaction design within two related areas: i) pedagogical effectiveness and efficiency of e-learning environments within the domain of surgical training; and ii) consumption of complex financial products and service quality within e-business environments.

Willem-Paul Brinkman is an Assistant Professor at Delft University of Technology, and an Associate Researcher at Brunel University in West London. His research area is in Human Computer Interaction where his work places a strong emphasis on the empirical evaluation of technology usage. He has published work on usability evaluation methods, adoption of broadband internet, personalisation of user interfaces, affective computing, social interaction, and e-health. In the medical domain, he has been working recently on virtual reality exposure therapy systems for the treatment of fear of heights, fear of flying, social phobia and posttraumatic stress disorder.