5-1-2021

Modern Practices for Flightcrew Training of Procedural Knowledge

Nathan Sonnenfeld

Blake Nguyen

Class Tido Boesser

Florian Jentsch

Repository Citation

Sonnenfeld, N., Nguyen, B., Boesser, C. T., & Jentsch, F. (2021). Modern Practices for Flightcrew Training of Procedural Knowledge. *84th International Symposium on Aviation Psychology*, 303-309. https://corescholar.libraries.wright.edu/isap_2021/52

MODERN PRACTICES FOR FLIGHTCREW TRAINING OF PROCEDURAL KNOWLEDGE

Nathan Sonnenfeld, Blake Nguyen, Class Tido Boesser, Florian Jentsch
University of Central Florida
Orlando FL

Instructional systems utilizing electronic and distance learning approaches (E&DL) have advanced the accessibility and capabilities of training in aviation and other industries. The aviation industry is particularly interested in how to extend the use of E&DL from training facts and information to training procedures, and how to integrate E&DL into existing training. We reviewed a corpus of literature including over 1,200 scientific, regulatory, and technical documents—across domains including aviation, defense, healthcare, and education—focusing on the effectiveness of E&DL for training procedures and the design, development, and evaluation of E&DL. We received input from subject matter experts with respect to contemporary and near-future aviation training practices, and also created a glossary of over 5,600 terms related to E&DL. In this paper, we discuss our findings and provide suggestions for their application to flightcrew training.

A priority for the aviation industry is training flightcrews on procedures, with an emphasis on those pertaining to corrective actions in response to non-routine and emergency situations on the flight deck (Human Factors & Aviation Safety, 2019). Training of procedures requires both the conveying of knowledge (declarative and procedural) and the practice of skills (Matton et al., 2018), and it is traditionally provided through either live training or high-fidelity simulation (Dunne et al., 2010). However, organizations increasingly use E&DL to satisfy learning needs (Martins, 2019), and this shift has only accelerated recently. The goal of our work was to identify guidance for the potential application of E&DL configurations to procedures training within the aviation industry. In support of this research, we also sought input from subject matter experts with respect to contemporary and near-future aviation training practices.

Findings & Recommendations

Within the space of E&DL in aviation, there are many approaches that employ recent developments in training design and technology. Like others (eg., ACT ARC 1-6, 2016), we found that the terminology is used inconsistently (Moore et al., 2011) and often conflates technologies with approaches, and vice versa. Relevant approaches (e.g., eLearning, online learning, computer-based training, technology-based training, simulation-based training) may each be combined with various hardware delivery mediums [e.g., personal computers (PCs), mobile devices, simulators, virtual reality (VR) or augmented reality (AR) displays and peripherals], as well as hardware and software technologies—ranging from common tools such as internet, multimedia, and simulation, to modern technologies including physiological sensors, learning analytics, and virtual agents. These instructional and technical choices are further crossed with pedagogic/didactic choices; training may vary in the location of delivery and the level of instructor involvement; most of this training may be conducted with or without instructors. Given the numerous ways relevant approaches and technologies may be combined or blended to form a specific configuration with which to deliver training, in the following, we will refer to the overall set as E&DL and describe specific facets as needed to distinguish different approaches.

E&DL without Task Simulation

Traditional eLearning/CBT. Executing procedures requires both knowledge and skills, and it is conventional wisdom in training that skills will only be learned if they are actively practiced – and the best practice opportunities in aviation involve on-the-job training or simulation. Despite this, training for procedures that uses E&DL without a simulation component still has been found to be more effective than no training (e.g., Potter et al., 2014). Furthermore, the literature suggests that this type of training can be equally or more effective than similarly focused classroom-based instruction—effectiveness of non-simulation E&DL largely depends on the design of each training. Evidence of this comes from (a) computer-based training (e.g., Kearns, 2011); (b) web-based training (e.g., Sitzmann et al., 2006); (c) multimedia/video (e.g., Keller et al., 2019); (d) webinars/video conferencing (e.eg., Abbot et al., 2017); and (e) intelligent tutoring systems (ITS; e.g., Kulik & Fletcher, 2016). In all of the aforementioned examples, learning tools such as video content and intelligent tutoring functionality were part of the training, and we therefore suggest them for inclusion in training of procedures using modern training approaches such as E&DL.

Mobile learning and microlearning. The literature provides some evidence that mobile learning, i.e., the use of mobile devices to access and display training content "*anywhere/anytime*", may be an effective training approach (Kearns, 2018). However, at this time, it is the least proven of all non-simulation training approaches. That said, some aviation training is already conducted using tablets and other mobile devices, and mobile devices have unique functionalities to support procedures training, including tactile interfacing, display of animated and interactive multimedia content, and collaborative Web 2.0 features (Tucker, 2010). While there are limitations to the use of mobile devices for training, most notably (small) screen size (Park et al., 2018), most of these could feasibly be resolved by adapting content to mobile devices (Bhuttoo et al., 2017) and using instructional methods suitable for mobile devices such as microlearning (Kearns, 2018). Further, mobile devices are potentially a low-cost solution to providing trainees with "anywhere/anytime" access to (limited) task simulation, as they can form the hardware basis for rudimentary VR (HMD) and AR (fusion of camera and training content) capability (see also below). Aviation practitioners who wish to include mobile learning as a component of procedures training should ensure that: (a) mobile instruction is accessible by other means; (b) mobile instruction is designed to utilize the unique capabilities of the medium; (c) mobile content is usable, accessible, and compatible to learners' devices; and (d) instructional content is designed with empirically supported strategies.

E&DL with Task Simulation

Scenario-based training (SBT). Based on our review of the literature, we determined that E&DL configurations using components of task simulations are generally more suitable for procedures training than those without it. Whether implemented as actual simulations (Reweti, et al., 2017; Walker, 2014) or more basic part-task scenario-based training (SBT; Blickensderfer et al., 2012), embedding relevant practice components into E&DL will improve the likelihood that trainees can acquire and apply procedural knowledge[1].

Game-based training. Potential exemplars for extending SBT further include intelligent tutoring, adaptive training, and automated scenario generation (Nicholson et al., 2009), and the used of game-based approaches. The latter, in particular, can be effective for improving cognitive skills (Sitzmann, 2011), although this evidence is more limited than for other simulation approaches, particularly in aviation contexts (cf. ACT ARC, 2016). Balancing engaging game elements with effective instruction is a difficult endeavor, however, necessitation the use of specialized personnel and development approaches (Hirumi & Stapleton, 2009), which may be infeasible for smaller carriers. Overall, aviation practitioners should consider leveraging SBT approaches when conducting procedural training and could further innovate this space by incorporating adaptive training, intelligent tutoring, automated scenario generation, and game-based elements within SBT approaches—while sharing the results of those efforts to strengthen and further advance E&DL research across and within the aviation community.

Virtual (and Augmented) Reality (VR/AR). VR promises to be a particularly suitable delivery medium for procedures training in contexts applicable to aviation. Extant studies generally show equivalence between VR and desktop configurations (Taylor & Barnett, 2011), although some VR configurations have been more effective than traditional training (Aggarwal et al., 2007) or computerized training on desktop displays, especially for novices, stationary operators, and for tasks involving contexts congruent with the flight deck (Taylor & Barnett, 2011). In a meta-analysis, Kaplan et al. (2020) found that Extended Reality (XR) platforms are more suitable for training physical tasks but are otherwise equally effective to traditional approaches. There is also some evidence that incorporating other modalities, specifically, emphasis on haptic interfaces, may improve the efficacy of VR training (Sigrist et al., 2013; Matton et al., 2018). AR has so far been limited to individual cases studies in the literature, but these have demonstrated that AR can be an effective medium for training knowledge, procedures, and spatial tasks (Hatfield et al., 2019). We believe that there are the following four future AR use cases: (1) using mobile technologies to capture field data (e.g., external views) and incorporate it back into the training environment (e.g., Medford et al., 2017); (2) visually overlaying training content such as text and video (Fehling et al., 2020; Keebler et al., 2017); (3) providing interactive procedural training across platforms (HMD, mobile, tablet, PC) (Hatfield et al., 2019); and (4) spatially overlaying procedural guidance (Limbu et al., 2018). In aggregate, while aviation practitioners should leverage immersive VR technologies in procedures training, we believe that although AR is a promising emerging technology, it remains unproven in the literature.

Evaluation of E&DL

To provide guidance on which training effectiveness evaluation (TEE) framework(s) may be suitable for the training evaluations when training and evaluation are conducted at a distance or without the presence of an instructor, we reviewed and qualitatively compared the most relevant, unique, and representative frameworks across identified categories, adapting criteria suggested by Dessinger and Mossely (2006): *feasibility*, *utility*, *propriety*, *accuracy*—and a fifth criterion, the *suitability* of each framework with respect to the evaluation of flightcrew training delivered using

[1] See also the discussion on levels 1 through 4 of eLearning in ACT ARC Recommendation 16-6 (pp.6-8); https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afx/afs/afs200/afs280/act_arc/act_arc_reco/media/2016/ACT_ARC_Reco_16-6.pdf)

E&DL configurations. Overall, we found that the selection of an evaluation framework should be based on a comparison of the unique advantages of each against training needs and organizational requirements, given that each TEE framework has unique advantages and limitations (e.g., Alvarez et al., 2004; Goodwin et al., 2018; Holton, 1996; Sitzmann & Weinhardt, 2019; Sottilare et al., 2012; cf. Kirkpatrick, 1959). While smaller carriers may not have the resources to implement every framework, training practitioners may be able to obtain more actionable training data by (a) assessing a greater scope of training factors and system affordances, (b) measuring learning, performance, and transfer at multiple levels; and (c) leveraging the unique capabilities inherent to E&DL systems—such as automated assessment and systems interoperability.

Conclusion

From our review of the literature on modern E&DL training approaches relevant to flightcrew training, and specifically the training of procedures, we can conclude that a number of them have promise for procedures training. Specifically, we found sufficient evidence configurations using video and/or VR, intelligent tutoring, and scenario-based practice that provide trainees with interactive opportunities to apply and practice the training content can generally be effective for procedures training, given it is appropriately designed. The empirical evidence supporting the application of mobile devices, game-based approaches, and AR to flightcrews' procedural training, on the other hand, is still comparatively limited, however, and air carriers should cautiously approach implementing these training practices. Lastly, to support training outcomes, air carriers should consider adapting their training evaluation practices by selecting TEE frameworks that are more suitable for the evaluation of training conducted using E&DL. In this context, tying data collected during and after E&DL training to subsequent performance in simulator training and to more distal outcome data is particularly important.

Disclaimer & Acknowledgements

The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the University of Central Florida or the Federal Aviation Administration (FAA). This work is sponsored by the FAA NextGen Human Factors Division (ANG-C1) under grant CRA 692M151940002.

References

Abbott, E. F., Thompson, W., Pandian, T. K., Zendejas, B., Farley, D. R., & Cook, D. A. (2017). Personalized video feedback and repeated task practice improve laparoscopic knot-tying skills: Two controlled trials. *Academic Medicine*, 92(11), 26-32. https://doi.org/10.1097/ACM.0000000000001924

Air Carrier Training Aviation Rulemaking Committee (2016). *Recommendation 16-6: Delivery of Cross-Functional CRM Training*. Federal Aviation Administration Flight Standards Service. Retrieved from https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afx/afs/afs200/afs280/act_arc/act_arc_reco/media/2016/ACT_ARC_Reco_16-6.pdf

Aggarwal, R., Ward, J., Balasundaram, I., Sains, P., Athanasiou, T., & Darzi, A. (2007). Proving the effectiveness of virtual reality simulation for training in laparoscopic surgery. *Annals of Surgery*, 246, 771–779. https://doi.org/10.1097/SLA.0b013e3180f61b09

Alvarez, K., Salas, E., & Garofano, C. M. (2004). An integrated model of training evaluation and effectiveness. *Human Resource Development Review*, 3(4), 385-416.

Bhuttoo, V., Soman, K., & Sungkur, R. K. (2017, July). Responsive design and content adaptation for e-learning on mobile devices. 1st International Conference on Next Generation Computing Applications (NextComp), Mauritius, 2017, 163-168. https://doi.org/10.1109/NEXTCOMP.2017.8016193

Blickensderfer, E., Strally, S., Doherty, S. (2012). The effects of scenario-based training on pilots' use of an emergency whole-plane parachute. *The International Journal of Aviation Psychology*, 22(2), 184-202. https://doi.org/10.1080/10508414.2012.663253

Dessinger, J. C., & Moseley, J. L. (2006). The full scoop on full-scope evaluation. In J. A. Pershing (Ed.), Handbook of Human Performance Technology: Principles, Practice, and Potential (3rd ed.) (pp. 312-330). Pfeiffer.

Dunne, R., Schatz, S., Fiore, S. M., Martin, G., & Nicholson, D. (2010, September). Scenario-based training: Scenario complexity. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 54, No. 27, pp. 2238-2242). Sage CA: Los Angeles, CA: SAGE Publications. https://doi.org/10.1177%2F154193121005402704

Fehling, A., Fedorovich, M., Johnson, M., Cunningham, J., Ariotti, S., Beck, S. (2020, May 12). *Microsoft Hololens 2 Roadmap, Applications and Experiences*. Webinar presented by the Central Florida Chapter of the VR/AR Association.

Goodwin, M. S., Reinerman-Jones, L., Harris, S., & Arrieta, A. (2018). A taxonomy for the evaluation of training simulations and environments. *MODSIM World 2018*. Retrieved from http://www.modsimworld.com/papers/2018/MODSIM_2018_Paper_not_required_for_a_43.pdf

Medford, A. L., Diaz, G., Murphy, J. S., & Goodwin, G. A. (2017). *Support for training effectiveness assessment and data interoperability (STEADI)*. U.S. Army Research Laboratory. Retrieved from https://apps.dtic.mil/sti/pdfs/AD1033634.pdf

Hatfield, N., Padron, C., Skinner, A., Fidopiastis, C., & Stanney, K. (2019). Augmented reality for training and operational support solutions. *MODSIM World 2019*. Design Interactive, Inc. Retrieved from http://modsimworld.org/papers/2019/MODSIM_2019_paper_56.pdf

Hirumi, A., & Stapleton, C. (2009). Applying pedagogy during game development to enhance game-based learning. In *Games: Purpose and Potential in Education* (pp. 127-162). Springer, Boston, MA. https://doi.org/10.1007/978-0-387-09775-6_6

Hoffman, R. R., Ward, P., Feltovich, P. J., DiBello, L., Fiore, S. M., & Andrews, D. H. (2013). *Accelerated expertise: Training for high proficiency in a complex world*. Psychology Press.

Holton III, E. F. (1996). The flawed four-level evaluation model. Human Resource Development Quarterly, 7(1), 5-21. https://doi.org/10.1002/hrdq.3920070103

Human Factors & Aviation Safety. *Hearing on The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification* before The House Committee on Transportation & Infrastructure, House of Representatives, 116th Cong. 1-17 (2019, December 11) (testimony of Mica Endsley). Retrieved from https://transportation.house.gov/imo/media/doc/Endsley%20Testimony.pdf

Kaplan, A. D., Cruit, J., Endsley, M., Beers, S. M., Sawyer, B. D., & Hancock, P. A. (2020). The effects of virtual reality, augmented reality, and mixed reality as training enhancement methods: A meta-analysis. *Human Factors*. https://doi.org/10.1177%2F0018720820904229

Kearns, S. K. (2018). Snap-courses: An instructional design strategy for aviation mobile learning. *The Collegiate Aviation Review International*, 31(1). Retrieved from https://search.proquest.com/scholarly-journals/snap-courses-instructional-design-strategy/docview/1502610549/se-2?accountid=10003

Kearns, S. (2011). Online single-pilot resource management: Assessing the feasibility of computer-based safety training. *The International Journal of Aviation Psychology*, 21(2), 175-190. https://doi.org/10.1080/10508414.2011.556499

Keebler, J. R., Patzer, B. S., Wiltshire, T. J., & Fiore, S. M. (2017). Augmented reality systems in training. In Brown, K. G. (Ed.), *The Cambridge Handbook of Workplace Training and Employee Development* (pp. 278-292). Cambridge University Press, New York, NY.

Keller, A., Langbauer, M., Fritsch, T., Lehner, F. (2019). Interactive video vs. hypertext documents - the effect on learning quality and time effort when acquiring procedural knowledge. *Proceedings of the 52nd Hawaii International Conference on System Sciences*, 22-31. https://doi.org/10.24251/HICSS.2019.005

Kirkpatrick, D. L. (1959). Techniques for evaluating training programs. *Journal of the American Society of Training Directors*, 13, 3–9.

Kulik, J. A., & Fletcher, J. D. (2016). Effectiveness of intelligent tutoring systems: A meta-analytic review. *Review of Educational Research*, 86(1), 42-78. https://doi.org/10.3102%2F0034654315581420

Limbu, B., Fominykh, M., Klemke, R., Specht, M., & Wild, F. (2018). Supporting training of expertise with wearable technologies: The WEKIT reference framework. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Mobile and Ubiquitous Learning: Perspectives on Rethinking and Reforming Education* (pp. 157-175). Springer Singapore. https://doi.org/10.1007/978-981-10-6144-8_10

Martins, L. B., Zerbini, T., & Medina, F. J. (2019). Impact of online training on behavioral transfer and job performance in a large organization. *Journal of Work and Organizational Psychology*, 35(1), 27-37. https://doi.org/10.5093/jwop2019a4

Matton, N., Vrignaud, C., Rouillard, Y., Lemarie, J. (2018). Learning flight procedures by enacting and receiving feedback. *Applied Ergonomics*, 70, 253-259. https://doi.org/10.1016/j.apergo.2018.03.009

Moore, J. L., Dickson-Deane, C., Galyen, K. (2011). E-learning, online learning, and distance learning environments: Are they the same? Internet and Higher Education, 14(2), 129-135. https://doi.org/10.1016/j.iheduc.2010.10.001

Nicholson, D., Schatz, S., Stanney, K., & Lackey, S. (2009). *Next-generation Expeditionary Warfare Intelligent Training (NEW-IT) Program Summary Booklet* (No. IST-CR-09-06). University of Central Florida, Institute for Simulation and Training. Retrieved from https://apps.dtic.mil/sti/pdfs/ADA514853.pdf

Park, E., Han, J., Kim, K. J., Cho, Y., & del Pobil, A. P. (2018, January). Effects of screen size in mobile learning over time. *Proceedings of the 12th International Conference on Ubiquitous Information Management and Communication*, 1-5. https://doi.org/10.1145/3164541.3164625

Potter, B. A., Blickensderfer, E. L., & Boquet, A. J. (2014). Training monitoring skills in helicopter pilots. *Aviation, Space, and Environmental Medicine*, 85(5), 543-549. https://doi.org/10.3357/ASEM.3771.2014

Reweti, S., Gilbey, A., Jeffrey, L. (2017). Efficacy of low-cost pc-based aviation training devices. *Journal of Information Technology Education: Research,* 16, 127-142. Retrieved from http://www.informingscience.org/Publications/3682

Sigrist, R., Rauter, G., Riener, R., & Wolf, P. (2013). Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review. *Psychonomic Bulletin & Review*, 20(1), 21-53. https://doi.org/10.3758/s13423-012-0333-8

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology*, 64(2), 489-528. https://doi.org/10.1111/j.1744-6570.2011.01190.x

Sitzmann, T., Kraiger, K., Stewart, D., Wisher, R. (2006). The comparative effectiveness of web-based and classroom instruction: a meta-analysis. *Personnel Psychology*, 59, 623-664. https://doi.org/10.1111/j.1744-6570.2006.00049.x

Sitzmann, T., & Weinhardt, J. M. (2019). Approaching evaluation from a multilevel perspective: A comprehensive analysis of the indicators of training effectiveness. *Human Resource Management Review*, 29(2), 253-269. https://doi.org/10.1016/j.hrmr.2017.04.001

Sottilaire, R. A., Goldberg, B. S., Brawner, K. W., & Holden, H. K. (2012, December). A modular framework to support the authoring and assessment of adaptive computer-based tutoring systems (CBTS). Retrieved from https://gifttutoring.org/attachments/download/222/2012_09_Sottilare_ITSEC%20Presentation_Paper%2012017.pdf

Tucker, J. S. (2010). Mobile learning approaches for US Army training (No. ARI-RN-2010-07). Army Research Institute for the Behavioral and Social Science. Fort Benning, GA. Retrieved from https://apps.dtic.mil/sti/pdfs/ADA528742.pdf

Walker, D. R. (2014). A quantitative study evaluating the impact of training context on performance in simulator-based aviation training (Order No. 3666754). ProQuest Dissertations & Theses Global. Retrieved from https://search.proquest.com/dissertations-theses/quantitative-study-evaluating-impact-training/docview/1640918106/se-2