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Modern Practices for Flightcrew Training of Procedural Knowledge

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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 (e.g., 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.g., 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
embedding relevant practice components into E&DL will improve the likelihood that trainees can acquire and apply procedural knowledge.

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, necessitating 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

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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/avs/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.

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