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Training Methods Research Opportunities for a Pilot Workforce in Transition: A Literature Review

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Abstract

Over the next 15 years, the U.S commercial air carrier workforce will undergo a significant turnover of 50% due to mandatory retirements, normal attrition, and airline expansion, resulting in a younger emerging pilot workforce comprised of Generations Y and Z, following the retirement of Baby Boomer and Generation X pilots. This paper provides an overview of the emerging pilot workforce and an analysis of training methods that may be used to train this workforce, including emerging technologies and associated learning methods. Understanding effective training and checking methods for the emerging pilot workforce may help guide curriculum development and research efforts to examine new technologies' efficacy and potential limitations in civilian flight training.

Keywords: pilot, training, checking, workforce

Introduction

The current commercial air carrier pilot workforce will lose almost 50% of its eligible pilot population within the next 15 years when they reach the mandatory retirement age, leaving an emerging pilot workforce that consists of Generations Y and Z. We reviewed relevant literature using government, EBSCO, and Google Scholar academic databases to identify the emerging pilot workforce, effective training methods for the emerging pilot workforce, and what new methods may be used in the future. Current methods include classroom instruction, computer-based training, flight simulation training devices, and aircraft training. New immersive technologies and associated learning methods to train military pilots may offer value in training the emerging civilian pilot workforce. There is little research examining the efficacy and limitations of such technologies in civilian flight training, and opportunities abound for further research to examine the efficacy and potential limitations of new immersive technologies in civilian flight training.

A Pilot Workforce in Transition

The commercial airline pilot workforce comprises passenger and cargo pilots who fly for air carriers certified under 14 CFR Part 121. This workforce is subject to volatility in air passenger and cargo demand, both shaped by world events. The terrorist attacks on September 11, 2001, sent shock waves through the aviation industry, decreasing demand for passenger air travel and commercial airline pilots. The decade that followed 9/11 saw multiple airline bankruptcies and mergers, a global recession, and stagnant pilot careers. Fewer prospective pilots entered the pilot training pipeline, and in the early 2000s, Federal Aviation Administration (FAA)-mandated retirement for Vietnam-era commercial airline pilots reaching age 60 began. In 2007 the Fair Treatment of Experienced Pilots Act changed the mandatory commercial airline retirement age from 60 to 65 years old, slowing workforce attrition for five years.

Demand for air travel rebounded in the decade following the economic recession of 2009, resulting in increased pilot hiring and the pilot workforce growing from 73,494 pilots in 2012 to 91,282 pilots in 2019 (Bureau of Transportation Statistics [BTS], 2021). The onset of the COVID-19 pandemic accelerated retirement for many senior airline pilots in 2020 as airlines worked quickly to cut operating costs to offset the plummeting demand for air passenger travel. The workforce lost 6,412 pilots in 2020 (BTS, 2021). Pilot hiring picked up in 2021 following the initial wave of the pandemic, and the workforce grew to 87,644 pilots. The total number of pilots in the U.S. pilot workforce is reported annually on Department of Transportation Schedule P-10: Pilots and Copilot Employment. Data for 2012-2021 is provided in Table 1 (BTS, 2021).

Table 1

Total Pilots - Major, National, and Regional Domestic Air Carriers, 2012 - 2021

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Pilot - Total	73,494	74,411	75,778	76,437	80,071	83,310	88,412	91,282	84,870	87,644

Note. The Department of Transportation categorizes air carriers per annual operating revenue. Major: Over $1 billion annual operating revenue; National: Over $100 million to $1 billion annual operating revenue; Large Regional: $20 - $99 million annual operating revenue; and Medium Regionals: less than $20 million annual operating revenues or that operate only aircraft with 60 seats or less (or 18,000 lbs. maximum payload).

Large commercial aircraft manufacturers Boeing and Airbus publish a strategic 20-year forecast each year. Both companies predict that the need for new pilots in North America will remain strong as the commercial aviation industry recovers from the impact of COVID-19. Boeing (n.d.) forecasts that North America will need 128,000 new pilots over the next 20 years, while Airbus forecasts the need for 97,000 new pilots in North America during the same period (Airbus, 2022).

Since 2001, the workforce percentage of civilian-trained airline pilots has increased while military-trained pilots hired into the airlines have decreased (U.S. Government Accountability Office [GAO], 2014). Over the last decade, clearly defined civilian pilot pathways have emerged, resulting from new partnerships between airlines, universities, and flight academies (Lutte & Mills, 2020) that accommodate increased hiring from civilian flight training entities. Collegiate aviation programs have played an increasing role in civilian pilot training production since the Colgan Air 3407 accident (Lutte & Mills, 2020), supplying regional airlines with pilots who perform well during new hire training (Smith et al., 2010; Smith et al., 2013; Smith et al., 2017; Smith et al., 2020). Multiple U.S. air carriers have developed, or are developing, *ab-initio* flight training programs that allow aspiring commercial pilots with a high school diploma or GED to follow a clearly defined path to employment with an air carrier.

The Airline Transport Pilot (ATP) certificate, with a minimum age qualification of 23, is required to be an airline pilot. Pilots who graduate from FAA-authorized higher education institutions may be eligible to apply for a restricted privileges ATP certificate at age 21. FAA statistics note that the average age of active ATP pilots (airmen who hold both an airmen certificate and a valid medical certificate) was 51.3 in 2021, and data from 2012 – 2021 is presented in Table 2 (FAA, 2023).

Table 2

Average Age of Active Airline Transport Pilots, 2012 – 2021

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Average Age	49.9	49.7	49.8	49.9	50.2	50.6	51.0	50.8	51.2	51.3

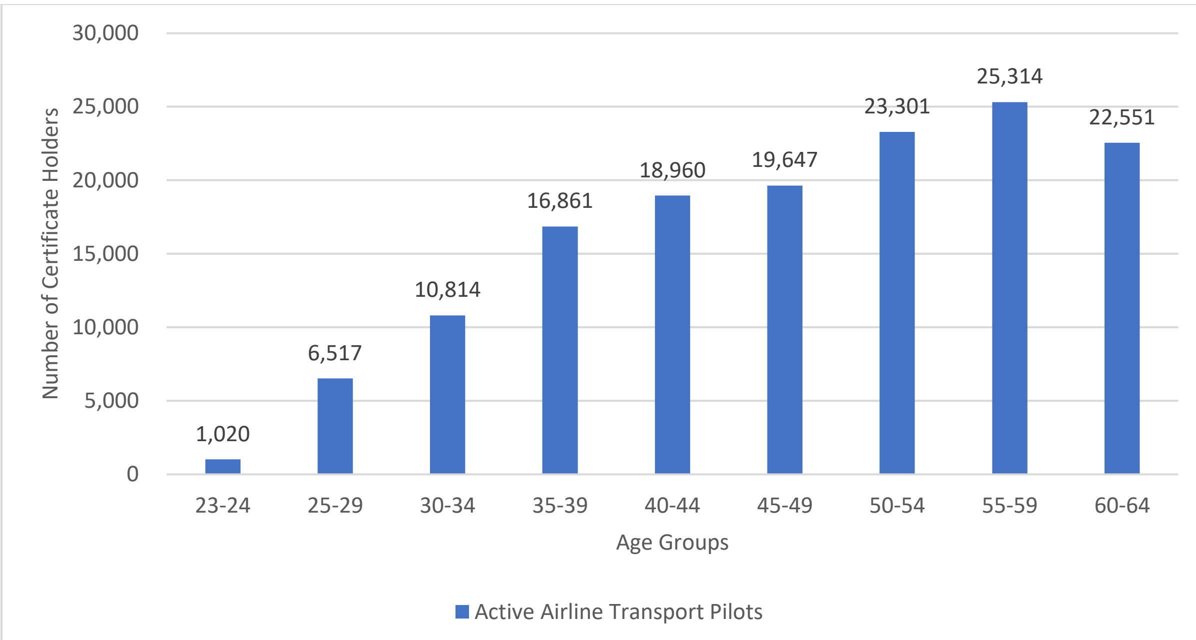
Note. Includes pilots with an airplane and/or a helicopter and/or a glider and/or a gyroplane certificate as of December 31, 2021. Pilots with multiple ratings will be reported under the highest rating. The FAA does not differentiate average age data between airplane, helicopter, glider, and gyroplane certificates. The minimum age to qualify for the ATP is 23 years old. Restricted privileges ATP data is not reported in *U.S. Civil Airmen Statistics.*

The estimated active ATP certificates held by age group data are presented in Figure 1. The FAA reports 144,985 active ATP pilots between the ages of 23 and 64 in 2021; of this number, 22,551

(15.6%) will reach age the mandatory retirement age of 65 within five years, and 71,166 (49.1%) will reach age 65 within 15 years (FAA, 2023).

Figure 1

Estimated Active Airline Transport Pilot Certificates Held by Age Group, 2021



Note. Includes pilots with an airplane and/or a helicopter and/or a glider and/or a gyroplane certificate as of December 31, 2021. Pilots with multiple ratings will be reported under the highest rating. The FAA does not differentiate average age data between airplane, helicopter, glider, and gyroplane certificates. The minimum age to qualify for the ATP is 23 years old. Restricted privileges ATP data is not reported in *U.S. Civil Airmen Statistics.*

The average age and flight hours of air carrier pilots who entered the Part 121 workforce were not available for mainline airlines, only for the five regional airlines that did the most pilot hiring between 2015 and 2018 in the 2018 Pilot Source Study (Smith et al., 2020). The average

age of 9,776 new-hire first officer pilots hired at five regional airlines between 2015 and 2018 was 34.0 years, and the average flight hours at the time of hire was 2,502. Notably, the standard deviation of hiring age was 9.9 years, indicating a wide variance in ages at the time of hire.

Generational Considerations

Howe and Strauss (1991) record that each generation is shaped by its social environment. Typically, generations are grouped into a range of birth years identified by a unique set of events that form shared ideas and beliefs (Dimock, 2019; Howe & Strauss, 1991; Williams et al., 2014). As a result, generations with similar life experiences can have similar traits. There are differences in the actual year groupings of each generation, but the intent is to identify the common characteristics of that group (Carlson, 2009; Dimock, 2019). The exception to this grouping technique is the Baby Boomer generation which was named and bound with beginning and ending years by the U.S. Census Bureau (Hogan et al., 2008). This paper uses the birth year ranges below, as established by the Pew Research Center (n.d.):

Baby Boomer Generation	Born: 1946-1964
Generation X	Born: 1965-1980
Generation Y (Millennials)	Born: 1981-1996
Generation Z	Born: 1997-2012

The age range on a commercial airline flight deck can range from 21 to 64 years, potentially spanning four generations. Table 3 identifies the estimated number of active commercial certificates and ATP certificates by generation (FAA, 2023). Most new hire airline pilot candidates will be from Generations Y and Z (FAA, 2023).

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Table 3

Estimated Active Airmen Commercial and ATP Certificates Held by Generation, 2021

Age Group	Generation	Commercial Certificate	ATP Certificate	Total (Commercial and ATP Certificates combined)
20-24	Gen Z	14,481	1,020	15,501
25-29	Gen Y	19,366	6,517	25,883
30-34		12,923	10,814	23,737
35-39		10,667	16,861	27,528
40-44	Gen Y & X	8,262	18,960	27,222
45-49	Gen X	6,493	19,647	26,140
50-54		7,357	23,301	30,658
55-59	Gen X & Baby Boomer	7,829	25,314	33,143
60-64	Baby Boomer	8,096	22,551	30,647
Total		**95,474**	**144,985**	**240,459**

Note. Includes pilots with an airplane and/or a helicopter and/or a glider and/or a gyroplane certificate as of December 31, 2021. Pilots with multiple ratings will be reported under the highest rating. The FAA does not differentiate average age data between airplane, helicopter, glider, and gyroplane certificates. The minimum age to qualify for the ATP is 23 years old. Restricted privileges ATP data is not reported in *U.S. Civil Airmen Statistics.*

The total number of commercial and ATP certificates held by Baby Boomers, Generation X, and Generation Y are similar. In contrast, the number of Generation Z pilot certificates is small as its members are just beginning to reach the age requirements to join the Part 121 workforce.

The pilot workforce as of 2022 comprises Baby Boomers, Generation X, Generation Y, and Generation Z. Baby Boomers will be exiting the pilot workforce within the next decade, leaving Generations X, Y, and Z at the helm. Generation X pilots are "digital immigrants" who were not "born into the digital world" but had, at some later point in their life, "become fascinated by and adopted many or most aspects of new technology" (Prensky, 2001, pp. 1-2). Generation X pilots will retire from the workforce between 2030 – 2045, leaving an emerging pilot workforce comprised of Generations Y and Z, both of whom are "digital natives" and are "native speakers of the digital language of computers, video games, and the Internet" (Prensky, 2001, p. 1). The objective is to collect research data that may inform FAA guidance on potentially effective pilot training and checking methods, including the emerging pilot workforce.

Research identifies characteristics unique to each generation that may influence how training is designed. Some argue that suggested differences between digital native and digital immigrant generations, regarding their ability to use technology to improve learning, do not exist. These researchers suggest that focusing on generational characteristics during curriculum development is ineffective (Bullen et al., 2011; Kennedy et al., 2007). Table 4 highlights many identifying characteristics when examining each generation in the general population.

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Table 4

Summary of Generational Characteristics

Generation X	Generation Y	Generation Z
	Virtual Reality (VR) motivates and engages (Reilly, 2012)	Brains wired to sophisticated, complex visual imagery (Hallowell & Ratey, 2011; Rothman, 2016)
	Attention span 12 seconds (Shatto & Erwin, 2016)	Attention span 8 seconds (Shatto & Erwin, 2016)
Hardworking, independent, skeptical (Lancaster & Stillman, 2002)	Prefers groupwork with hands-on experiences (Eckleberry-Hunt & Tucciarone, 2011); Team-oriented (Howe & Strauss, 1993)	Self-directed learners; thrive on technology (Shatto & Erwin, 2016); Prefers interactive games, collaborative projects, and challenges (Rothman, 2016)
	"How-to" guide for success (Monaco & Martin, 2007; Reilly, 2012); Wants immediate feedback and lacks critical thinking skills (Monaco & Martin, 2007);	Likes Google, lacks ability to vet information (Pew Research Center, 2014; Shatto & Erwin, 2016)
	Less lecture with creative, interactive, fun learning (Eckleberry-Hunt & Tucciarone, 2011)	Prefers less lecture and more interaction (Shatto & Erwin, 2016)
"Digital immigrants" (Prensky, 2001)	"Digital natives" (Prensky, 2001)	"Digital natives" (Prensky, 2001)
	Prefer to multi-task rather than focus on one thing (McCrindle Research, 2006 Worley, 2011)	

Fussell and Thomas (2021) record that little has changed in the characterization of flight students over the years. They note research from Campbell et al. (2009), Fitzgibbons et al. (2004), and Gao and Kong (2016) that characterize "pilots and flight students as emotionally stable, highly assertive and conscientious, competitive and striving for high achievement, and tending toward higher levels of extraversion" (Fussell & Thomas, 2021, p. 5). Furthermore, they highlight findings by Harriman (2011) and Kanske and Brewster (2001), who found that "flight students use reasoning, theoretical models, and observations to form explanations and may prefer abstract conceptualization, in which learning occurs through logical thinking and planning" (Fussell & Thomas, 2021, p. 5).

Training Methods and Technology

The emerging pilot workforce includes individuals who identify as adult learners (Brady et al., 2001), meaning they are goal-oriented, self-directed learners (Houle, 1961; Knowles et al., 2015), and perform best when their educational environment is based on adult learning principles (Brady et al., 2001). They embrace active learning (Niemczyk, 2020; Williams et al., 2014), and individual learning can improve using cooperative learning strategies that also aid in preparation for success in a team working environment (J. F. Clark, 2001; Graham, 2017).

Martinussen and Hunter (2010) describe training as a systematic process of developing knowledge, skills, and attitudes to some specified level of competency. Pilot training involves instruction in procedural and technical skills and education in non-technical skills, such as crew resource management, decision-making, leadership, and communication (Sommer, 2014). Scenario-based training is encouraged (Cassens et al., 2011) as it promotes critical thinking and decision-making skills (Craig, 2009). Training organized and presented in the following format is proposed as an effective strategy: 1) information/concepts; 2) demonstration/briefing; 3) practice/simulation (maximize as able – more repetitions equal more decisions, build situation models); and 4) feedback/debrief (self and with instructor) (Mumaw et al., 2020; Salas et al., 2012). A combination of methods is used in pilot training, including classroom instruction, computer-based training, and practical training in flight-training devices and aircraft (Schaffernak et al., 2020). Using various instructional methods benefits training (Mavin & Roth, 2015). This paper focuses on literature since the turn of the century, when the youngest members of the emerging pilot workforce may have begun pilot training.

Research suggests that classroom-based instruction methods are effective for human factors instruction (Dusenbury & Olson, 2019), learning aircraft systems (Wilson & Stupnisky, 2022), teaching weather technology (Cobbett et al., 2014), and upset-recovery training (Rogers & Boquet, 2012).

In the early 1990s, Computer-based training (CBT) was seen as part of the future of aviation training, especially in developing technical skills (compared to behavioral skills), since only a few expert instructors had to deliver instruction in a lecture format. All trainees received the same correct information (Orlady, 1993). With the proliferation of the internet and the development of smartphones, tablets, and mobile applications, the concept of CBT has evolved well beyond the desktop computer. It is now commonly known as electronic learning or eLearning. It provides organizations with a means to deliver training to many users through multiple channels and formats, and pilots have become increasingly accepting of and confident in this method (Raisinghani et al., 2005). Learning may be synchronous or asynchronous, self-paced or instructor-led, offered remotely or onsite. Asynchronous eLearning allows the learner to control the content sequence of pacing instruction (Kearns, 2010). Self-pacing may lead to a higher level of motivation (R. C. Clark & Mayer, 2008, as cited in Kearns, 2010) and may be a good strategy for novice skill-based learning (Kraiger & Jerden, 2007). To determine the effectiveness of eLearning, Kearns (2010) reviewed multiple studies (Bernard et al., 2004; R. E. Clark, 1994; Kulik & Kulik, 1991; Russell, 1999; Zhao et al., 2005) and concluded that, in general, one could expect no significant differences in learning outcomes between eLearning and classroom-based courses developed with the same instructional content. Additionally, Kearns (2010) found asynchronous eLearning results in better learning than synchronous eLearning; blended learning results in better education than either synchronous or asynchronous delivery alone; and eLearning is more effective than classroom instruction for teaching declarative knowledge (e.g., ability to cite regulation) and equally effective for procedural knowledge (e.g., learning a standard operating procedure). eLearning may also be an effective instructional method to foster nontechnical flight skills (Bolstad et al., 2010; Kearns, 2011; Potter et al., 2014). Interactive eLearning multimedia tools that provide user feedback, self-testing, construct visualization, and encourage sequential movements, help learners develop procedural knowledge (Matton et al., 2018). eLearning curriculum has traditionally been delivered in the 2D environment, but technological advances make eLearning in 3D more readily available (Kearns, 2010; Kearns et al., 2020). eLearning provides a data-rich environment, and when combined with an intelligent tutor, where the training program automatically increases the difficulty level in response to student performance, a zone of optimal learning occurs known as adaptive learning (Brown, 2020; Kearns et al., 2020).

Flight simulators and training devices have become widely used in commercial aviation since the 1960s (Schaffernak et al., 2020) and provide increased efficiency, safety, and lower training costs (Harris, 2011). Simulators vary according to the level of fidelity they entail, that is, the degree to which the simulator mimics the real-world task (Myers et al., 2018). The level of fidelity can also be subdivided into physical and psychological-cognitive fidelity fields (Macchiarella & Mirot, 2018). High physical fidelity implies that the device replicates the real-world task regarding sound, visual input, and sensation. High psychological-cognitive fidelity means that the simulator replicates the real-world task's psychological and cognitive aspects (e.g., mental workload, psychological pressure, attentional demand) to a high degree. Higher-fidelity simulation does not mean better training occurs (Salas et al., 1998) as novice learners may experience cognitive overload and derive little benefit from high-fidelity simulation (Jones, 2021). Studies have shown that lower-level fidelity (e.g., desktop computer-based) simulation devices can effectively train initial “stick and rudder” skills (Reweti et al., 2017; Risukhin et al., 2016; Stewart et al., 2008), initial Instrument Flight Rules (IFR) training (Taylor et al., 1999) and maintenance of instrument flight skills (Taylor et al., 2005; Thomas, 2018), and crew resource management (CRM) skills (Brannick et al., 2005; Johnson et al., 1997; Rosa et al., 2021), boosting pilot cognitive and behavioral skills. Lower-fidelity simulation, which complements higher-fidelity simulation, may serve as a resource in developing resilient pilots (Dahlstrom et al., 2009) and help train pilots to cope with information conflicts (Carroll et al., 2021). Higher-level fidelity flight training simulation devices reduce aircraft training requirements (McLean et al., 2016) and effectively support pilot certification task training (Macchiarella et al., 2008), practical, scenario-based training to develop cognitive skills required to avoid midair collisions (Koglbauer, 2015), airport procedures training (Koglbauer & Braunstingl, 2018), and improve working memory and situation awareness training (Zhou et al., 2022). Airline simulation training scenarios can be improved by organizing training using a variable and unpredictable approach (Landman et al., 2018) so that training does not become predictable with little generalizability beyond the training environment (Casner et al., 2013).

Gamification is the use of game design elements (e.g., rules, goals, challenges, rewards) in non-game contexts (Deterding et al., 2011) and has been shown to contribute to improved learning (Zainuddin et al., 2020). Gamification designs provide immediate feedback (e.g., badges, points), which is often engaging, positive, and constructive (Jain & Dutta, 2019). Feedback plays a significant role in learning (Pashler et al., 2005), especially at the earlier stages. Positive feedback has been associated with higher levels of competence, which can lead to increased motivation and better learning (García et al., 2019; Wulf & Lewthwaite, 2016).

Gamification has been shown to benefit Flight Management System (FMS) preflight programming training (Mautone et al., 2008), is believed to be a possible method to supplement simulation-based training (Kuindersma et al., 2015), and has been shown to supplement flight instructor training in assessing pilots' non-technical competencies (Dapica et al., 2022).

Immersive technologies create a virtual world. Virtual reality (VR) and augmented reality (AR), and a combination of both technologies, referred to as mixed reality (MR), have been tested as possible training enhancement methods (Kaplan et al., 2020; Kearns et al., 2020). VR, AR, and MR fall under the umbrella term extended reality (XR), in which the "X" represents a variable for current or future technologies that combine real and virtual environments (Cross et al., 2022).

Military flight training programs have demonstrated the potential behind immersive devices in pilot training. The U.S. Air Force began an initiative to innovate and improve undergraduate pilot training when it established its first Pilot Training Next (PTN) class in Austin, Texas, in 2018. This program was designed to revolutionize flight training content delivery using a combination of multimodal immersive learning platforms derived from commercial-off-the-shelf (COTS) technologies and artificial intelligence (AI) tutoring systems (Lewis & Livingston, 2018). Students had their own synthetic virtual environment training stations in the classroom. They also shared a training station in their housing dormitories, providing easy access to a virtual flight training device to practice piloting skills. Intelligent tutors built into the synthetic training systems allowed PTN to have a higher student-to-instructor ratio and allowed instructors to concentrate on more complex maneuvers where higher levels of judgment and decision-making were required (Lewis & Livingston, 2018). PTN students completed their first solo, on average, on their sixth or seventh ride versus the 13th or 14th ride,

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the traditional norm (Lewis & Livingston, 2018). The Air Force continues to build upon lessons learned to develop an AI-driven adaptive learning framework that engages and motivates learners in individualized ways that traditional pilot training methods cannot, using learning styles, knowledge levels, and skill proficiency while avoiding learning content that the student has already mastered (Lewis et al., 2019). The Air Force applied the PTN model in the Powered Flight Program at the U.S. Air Force Academy. Initial effectiveness data indicated increased perceived self-efficacy related to increased virtual reality simulator time (Pennington et al., 2019). The U.S. Army developed the Aviation Training Next (ATN) program, which employed VR simulation in initial rotary-wing training. They found that statistically, there is no difference between traditional and ATN flight student performance in course management plans, but that ATN students continually outperform their peers in aircraft check rides and academics beyond ATN training (McFarland, 2020). The U.S. Navy's Naval Aviation Training Next (NATN) program, also known as Project Avenger, re-imagined conventional training methodologies by employing a competency-based, individually tailored learning approach integrated with emerging technologies (focused on VR) for progressive skills development and flexible training event design, based on lessons learned from earlier military efforts (Mishler et al., 2022). The first iteration of NATN suggests that this new method produces a stronger generalized aviator faster than legacy training, and student feedback was overwhelmingly positive (Mishler et al., 2022).

Immersive XR training devices have been introduced in commercial aviation, but academia has generated little empirical evidence of XR effectiveness due to hardware constraints (Cross et al., 2022). Bauer and Klingauf (2008) suggest that VR may help develop procedural knowledge that improves simulator performance, filling a niche between CBT and the traditional flight simulator that may supplement classroom training activities and simulator procedure training (Cross et al., 2022). Schaffernak et al. (2022) identify the three most promising use cases for MR in pilot training: interactive theory training, cockpit procedure training, and outside check training. Moesl et al. (2021) propose a research agenda for implementing AR-based training into *ab-initio* pilot training that focuses on approach and landing, abnormal and emergency procedures, air work, enroute procedures, and flight instructor development. They also propose incorporating eye-tracking, which research suggests may improve training for flight deck monitoring (Lefrançois et al., 2021), attention allocation (Dehais et al., 2017), and situational awareness (Yu et al., 2014). When compared to traditional flight simulator training devices, Cross et al. (2022) summarize the benefits of XR as reduced cost, flexibility, immersion/realism, and limitations, such as the degradation of performance due to hardware limitations and useability of virtual controls and virtual reality sickness.

Macleod (2001), Martinussen and Hunter (2010), and Kearns (2010) promote pilot training based on sound theoretical principles of learning using a systematic approach, such as the Analyze, Design, Develop, Implement, and Evaluate (ADDIE) model. ADDIE provides a rigorous iterative framework for training development yet is adaptable since it does not prescribe specific training methods or modes (Martinussen & Hunter, 2010). Currently, over 90% of U.S. airline pilots, particularly at bigger airlines, train under the systematic Advanced Qualification Program (AQP), a voluntary training program developed over 30 years ago through a partnership between the FAA and U.S. air carriers (Farrow, 2019; FAA, 2022). AQP, outlined in 14 CFR Part 121 Subpart Y, is a proficiency-based flexible approach to training and checking and a philosophical shift from the traditional prescriptive approach to training and checking (e.g., programmed hours) found in 14 CFR Part 121 Subparts N and O. AQP uses a data-driven systematic approach that allows training program flexibility, incentivizes air carrier participation, and integrates scenario-based individual and crew training and evaluation. AQP is chiefly used at large (over 1,000 pilots) and medium-sized (501-999 pilots) Part 121 air carriers (FAA, 2022). In comparison, 95% of small (less than 500 pilots) Part 121 air carriers choose not to use AQP and instead follow traditional training rules (FAA, 2022).

Analysis and Discussion

Collaborating with industry and regulators, collegiate aviation programs can fill the void of research examining the efficacy and limitations of new immersive XR technologies and associated training methods that may augment current general aviation and commercial air carrier training. Leveraging the emerging pilot workforce's ability to embrace innovative technologies and appreciation for active learning may lead to improved development of the knowledge, skills, and attitude needed from a professional pilot. New technologies and training methods may allow a more tailored approach to training than previous one-size-fits-all approaches, particularly in a well-designed, data-based, iterative instructional system.

Conclusion

The commercial pilot workforce will undergo a 50% turnover during the next 15 years. The emerging pilot workforce will consist primarily of civilian pilots who are members of Generations Y and Z. Research suggests this workforce should be trained using a combination of traditional classroom instruction, computer-based eLearning, and hands-on scenario-based practical training in lower-level fidelity and higher-level fidelity flight-training devices and aircraft. The emerging pilot workforce is accustomed to incorporating innovative technologies into their lives. As new technologies and associated training methods, particularly those that support active and self-directed learning, demonstrate value to pilot training through research, they may be considered for FAA evaluation and training use.

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