January 2020

Pilot Perception Of Automation Use: A Generational Assessment

Ryan Leadens

Recommended Citation

Leadens, Ryan, "Pilot Perception Of Automation Use: A Generational Assessment" (2020). *Theses and Dissertations*. 3106.
https://commons.und.edu/theses/3106

PILOT PERCEPTION OF AUTOMATION USE: A GENERATIONAL ASSESSMENT

by

Ryan E. Leadens
Bachelor of Science, University of Minnesota—Crookston, 2007

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota

May
2020

This thesis, submitted by Ryan Leadens in partial fulfillment of the requirements for the Degree of Master of Science in Aviation from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

DocuSigned by:
0AC0753522AE45C...
Mark Dusenbury, PhD

DocuSigned by:
6706D21C81124B7...
Shayne Daku

DocuSigned by:
Gary Ullrich
2EF9A89CB334466...
Gary Ullrich

Name of Committee Member 3

Name of Committee Member 4

Name of Committee Member 5

This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

DocuSigned by:
Chris Nelson
13D0157109424B1...
Chris Nelson
Dean of the School of Graduate Studies

4/23/2020
Date

PERMISSION

Title	Pilot Perception of Automation Use: A generational assessment
Department	Aviation
Degree	Master of Science

In presenting this thesis in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my thesis work or, in his absence, by the Chairperson of the department or the dean of the School of Graduate Studies. It is understood that any copying or publication or other use of this thesis or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and the University of North Dakota in any scholarly use which may be made of any material in my thesis.

Ryan Leadens
04/23/2020

ABSTRACT

As flight deck technology has become more advanced, the pilot–machine interaction has become a larger point of emphasis in pilot training programs. Increasing demand for air travel in future decades will create greater need for highly accurate and reliable navigation systems. These systems reduce a pilots' exposure to "stick and rudder" skills while increasing the knowledge and situational awareness required to operate safely.

It is imperative that pilots are properly trained on these systems prior to conducting line operations. In order to create an efficient and effective training program, it is important to understand how pilots perceive their role on the modern flight deck and how they prefer to learn the functionality of automated aircraft systems, ranging from auto-flight modes to an aircraft's flight management system. Perception plays a role because it can display vulnerabilities to certain types of errors in the flight deck. Important factors include levels of trust in automation, system knowledge, and how system functionality are taught.

This study used an online survey to gather information regarding pilot perceptions of automation use, and analyzed the data from a generational standpoint. Pilots offered their opinions on automation use and training. The results showed that younger generations of pilots have higher levels of trust in automated systems and their components, as well as higher levels of confidence in using various levels and modes of these systems. Pilots also ranked the effectiveness of various methods used during training. Those results showed that pilots of older generations preferred a more traditional hierarchical educational setting, whereas younger pilots were more open to interactive methods. Common preferences were also observed among pilots of all generations in supplemental training materials as well as well as other training techniques.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to the members of my advisory committee for their guidance and support during my time in the master's program at the University of North Dakota.

CHAPTER I

INTRODUCTION

Although it may come as a surprise to the traveling public, pilots utter the phrase, “Now what is it doing” on a regular basis while flying large commercial aircraft full of hundreds of passengers or thousands of pounds of cargo worldwide. The good news is that when a pilot is unsure what is happening, it is rare that any sort of equipment malfunction actually exists. The more likely scenario is that there is simply a disconnect between the flight path or behavior of the aircraft that is being observed and what was expected by the pilot. When the disconnection leads to breakdowns in the interaction between human operators and automated systems, it is known as automation surprise (Sarter et al., 1997). These unexpected events can degrade the situational awareness of the pilot, and in some cases the safety of the flight. As cockpits of modern transport aircraft become more advanced, the human operator’s required skillset has focused less on being the direct manipulator of the aircraft’s control surfaces, to more of a manager of automated systems with varying modes of operation. Thus, the interaction between human and machine in the modern flight deck has become a focal point for airline training programs.

The demand for advanced flight deck technology will continue to increase in decades to come, as global air traffic is expected to increase rapidly. In the passenger-airline industry alone, the International Air Transport Association (IATA) expects 7.8 billion passengers to travel in the year 2036. That is double the roughly 4 billion who traveled in 2017 (IATA, 2017). This presents great opportunities for the aviation industry, yet also introduces many challenges. As Increased manpower, infrastructure, and technological innovation will be needed to support the increase in demand. Although recent technological advancements have made strides in integrating unmanned aerial systems (UAS) into the National Airspace System (NAS) in the United States, for the foreseeable future, the attention will remain on having well educated and highly trained human operator at the controls of transport aircraft. With that said, one of the most notable challenges facing the industry is recruiting and training enough pilots to operate highly automated aircraft in an increasingly complex environment around the globe.

In 2018, Boeing released the Pilot and Technician Outlook, which projected a need for 790,000 pilots over the next twenty years worldwide, including 206,000 in North America alone (Karantzavelou, 2018). Consequently, the future generation of airline pilots will find themselves operating large, highly automated machines with far less aviation experience than past generations of pilots. Manufacturers continue to incorporate highly automated systems into flight decks to increase efficiency; therefore, operators continue to search for strategies and methods to rapidly train their pilots.

The growth of the airline industry will undoubtedly bring unprecedented challenges to operators and training departments. The Federal Aviation Administration's (FAA) Next Generation Airspace Initiative is one of the largest contributors to the rapid advancement of automated flight decks. The multi-year program is transforming the national airspace system to create a safer, more efficient, and environmentally friendly system. As procedures evolve, the training of operators will need to follow suit. Presently, little is known about how the next generation of pilots can best learn the required skillset needed to excel in this environment.

Throughout the last several decades, automation research has emphasized the deterioration of pilots manual flying skills, and studies supported this claim, with the FAA claiming that pilots have become too dependent on aircraft systems and either haven't adequately learned or have not maintained their ability to manually control their aircraft (Niles, 2019). A 2014 study found that pilots with a lower level of recent practice and more time since flight training had larger deviations from ideal approach parameters (Haslbeck et al., 2014). A 2013 study by the FAA found that pilots lack sufficient or in-depth knowledge and skills to properly control their plane's trajectory, partly because current training methods, training devices and the time allotted for training may be inadequate to fully master advanced automated systems (Pasztor, 2013). This inadequacy is partially due to the disconnection between cockpit design and operator training. As automation management takes on a greater emphasis in pilot training, what remains a relatively unknown is what airline pilots' perceptions are of the automated systems they operate and how they are trained. Furthermore, it is necessary to know whether those perceptions vary between members of various generations, as the industry prepares for the decades ahead.

In the future, it will be imperative that the evolution of training methods parallels the evolution of the advanced cockpits and environment in which pilots are required to operate. New training apparatus, delivery methods, and supplemental documentation will need to be used to streamline training pipelines and keep pilots flying operationally. The evolution of the academic environment at all levels of education will mean that pilots entering the industry will learn more efficiently if their classroom setting is properly adjusted to their most effective method of learning. In the operational environment it is imperative that pilots not only have appropriate knowledge, but also a level of trust in their aircraft systems to operate safely.

A strong pilot skillset to support busy line operations is built in the training phase, where operators have traditionally used a classroom setting to teach how automated systems work and use varying levels of flight simulators in order to provide pilots with the cognitive repetitions required to establish the appropriate muscle memory and practical knowledge. As the industry evolves, so must the methods used to train pilots to achieve the desired skillset. It is important, then, to acknowledge that future generations of pilots may achieve optimal performance in the cockpit by using different training methods than members of generations before them. This is due to the fact that their Educational experiences and perceptions of the skillset could be different for members of different generations. This study aims to answer key questions regarding pilot perceptions of the automated systems they operate, as well as the training methods used to train them for such operations. The research will also consolidate data specific to determining how pilots of varying generations perceive automated flight decks.

Purpose of the Study

The purpose of this study is to examine pilot perceptions of automation use and their preferred methods of training on these systems. It examines the perceptual differences between pilots of different generations in order to gauge whether they believe automation management is an integral part of their overall skillset or that it detracts from what they perceive as their core piloting skills. A review of the literature on automation levels was conducted, and focuses on the high demand for automated systems in the future, the safety advantages of such systems, and the challenges that they create for operators. This research includes a review of cognitive models addressing the threat of automation surprise and mode confusion among pilots. A review of generational differences in education and learning styles was performed. Finally, previous research on training methods was reviewed along with technological advances of future pilot training systems. This research aims to answer the following research questions.

1. Do Millennial and Generation Z pilots display higher levels of trust in automated aircraft systems than Generation X and Baby Boomer pilots?
    a. Do generational differences impact pilots’ preferences for flying with various levels of automation engaged?
    b. Do pilots perceive automation management as an integral skill, or do they believe it detracts from their overall skillset?
2. Do pilots initially prefer to learn new aircraft procedures and maneuvers manually before proceeding with automated components?
    a. Do pilots from different generations prefer different training delivery methods?

Literature Review

Automation Levels and Advantages

As technology continues to evolve, the modern cockpit continues to become more automated. The competitive advantage these systems provide comes in multiple forms. Reduced weather minima and improved flight path control allow for higher traffic volume and on-time operations. The extremely high reliability rate of automated systems has created a safer, more efficient operating environment. For pilots, proper automation management results in a reduced workload and increased situational awareness. Additionally, aircraft maintainers benefit from faster and more accurate diagnosing of aircraft malfunctions and inoperative equipment.

An integrated meta-analysis in 2014 validated previous research and noted that medium levels of automation would represent an optimal choice with respect to primary performance improvements and workload reductions by, at the same time reducing unwanted performance consequences in terms of loss of situational awareness and difficulties of return-to-manual performance (Onnasch et al., 2014). When a real or perceived malfunction exists, higher degrees of automation correlate with worsening performance. This analysis assumes the system is performing as expected (Onnasch et al., 2014).

Modern transport aircraft typically have a series of automated systems that can be operated independently or in conjunction with each other. These systems typically include the following: an auto-throttle or auto-thrust system, auto-pilot, flight director, mode control panel, flight management system (FMS), and flight mode annunciator (De Boer & Hurts, 2017). These systems are tightly coupled and enable partially or fully automated flight, when required. The human pilot is then tasked with selection of the appropriate level of automation, which can range from fully automated to fully manual. A very broad example of varying levels of automation was developed by Parasuraman and Sheridan (2000), through a 10-point scale, with higher levels representing increased autonomy of computer over human action (Parasuraman et al., 2000). In commercial aviation, individual operators often define their own levels of automation for their pilots, with specific criteria based on aircraft systems and company standard operating procedures (SOP's), such as which systems (auto-pilot, flight directors, auto-thrust, etc.) are to be engaged at each level depending on the phase of flight or type of procedure.

Table 1

Levels of Automation of Decision and Action Selection

Automation level	Requirements
HIGH	The computer decides everything, acts autonomously, ignoring the human
	Informs the human only if it, the computer, decides to
	Informs the human only if asked
	Executes automatically, then necessarily informs the human, and
	Allows the human a restricted time to veto before automatic execution, or
	Executes that suggestion if the human approves, or
	Suggests one alternative
	Narrows the selection down to a few, or
	The computer offers a complete set of decision/action alternatives, or
LOW	The computer offers no assistance; human must make all decisions and actions

Note. From *A Model for Types and Levels of Human Interaction with Automation,* by Parasurman et al, 2000.

Often, proper use of varying levels of automation can create better situational awareness, allowing pilots to feel more comfortable using each of their aircraft's automated systems and each of their modes. Pilots' willingness to fly without certain components of automation may not indicate a lack of trust, but rather a form of comprehension when it comes to operating each component. Pilots should feel comfortable enough with their knowledge of each component that they can eliminate it and manually perform that component's function. This knowledge defines a skillset in which pilots are not merely observers but rather human and machine are operating as a single joint cognitive system.

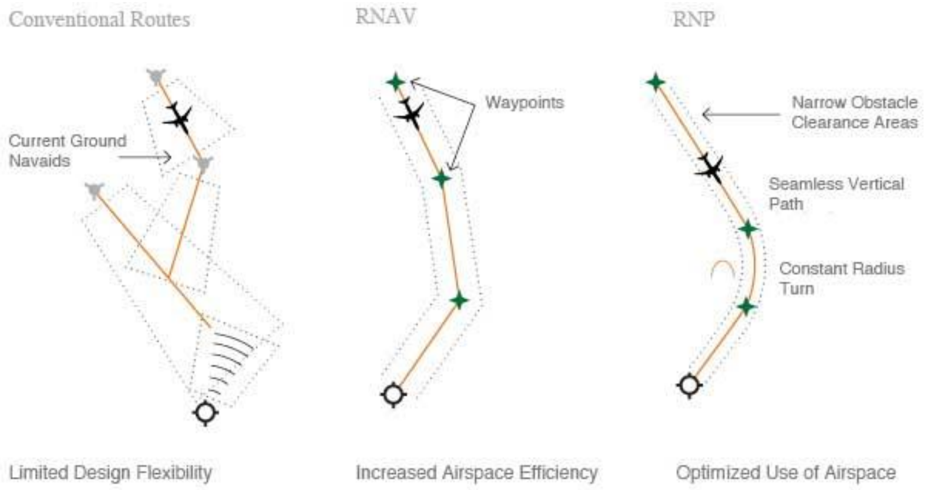
Regulatory Environment

The level of automation used is generally at the discretion of the pilot and dependent on the environment with consideration of factors such as airspace, procedure complexity, terrain, weather, and air traffic. However, due to the increase in volume of air traffic and advances in modern technology, the industry continues to see tightening parameters associated with departure, arrival, and approach procedures. In addition to equipment installation and performance requirements, some procedures are strongly encouraged, whereas others require the use of automated systems to control the aircraft's flight path. It is common for an operator to restrict pilots from manually flying the aircraft under certain parameters to receive the highest certification levels and promote safe operations.

The NextGen program has developed over the last decade, driven by increasing use of space-based navigation aids in addition to or in lieu of conventional ground based navigational aids. The concept, known as Performance Based Navigation (PBN) often uses area navigation (RNAV) and required navigation performance (RNP) procedures for departing and arriving aircraft. The tighter parameters of these procedures allow for optimal flight path management, particularly to avoid obstacles or in mountainous terrain, or to avoid over flight of certain environmentally or noise sensitive areas. Figure 1 illustrates the difference between conventional, RNAV, and RNP flight paths.

Figure 1

Comparison Between Conventional, Area Navigation, and Required Navigation Performance Routes



(Nakamura & Royce, 2008)

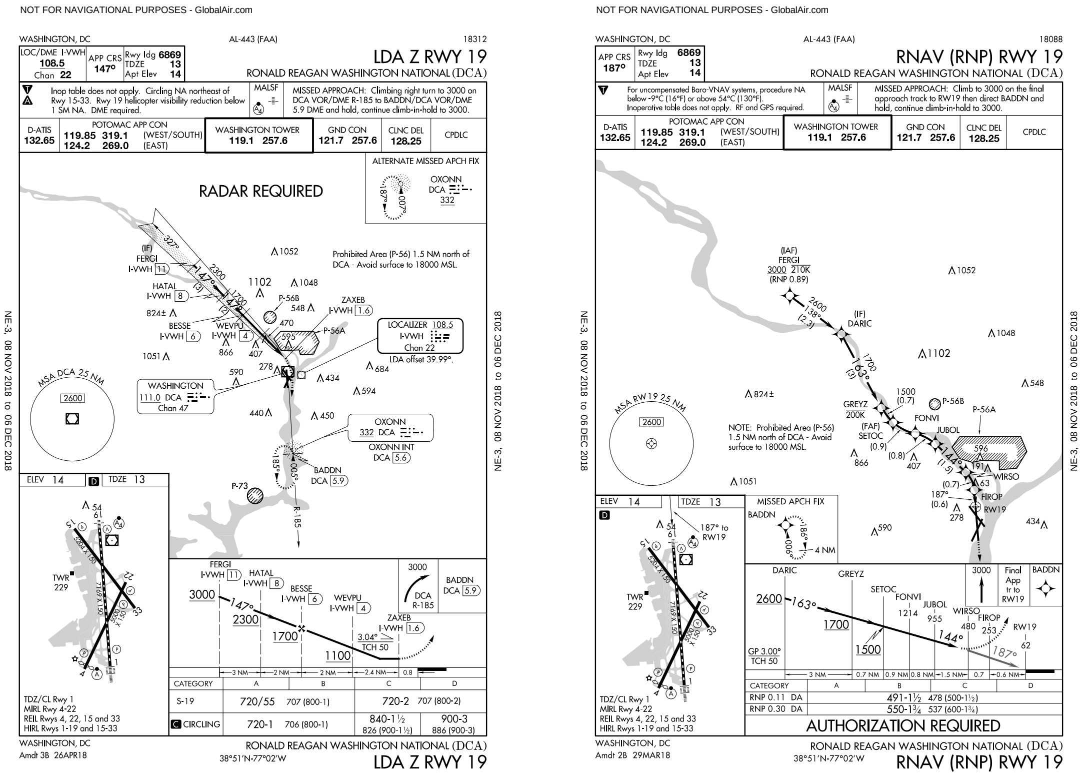
PBN procedures create a safer and more optimal flight path and also provide an economic boost in the form of fuel savings. Pamplona and Alves (2015) conducted a study featuring 10 aircraft types from four manufacturers and compared fuel-consumption rates using conventional versus PBN procedures. Results varied by aircraft model but overall, gains of RNP when compared to conventional were between 0.73% and 4.89% fuel savings, with aircraft model E145 presenting the best gain, with 4.89% (Pamplona & Alves, 2015).

The need for PBN procedures, along with pilots and aircraft capable of maintaining their parameters are in particularly high demand in densely populated cities, where aircraft fly in close proximity to special-use airspace or other airports. Figure 2 illustrates the contrast between the traditional localizer type directional aid (LDA) Z RWY 19 approach and the optimal RNAV (RNP) RWY 19 approach at Washington, DC's Reagan Airport. Although the LDA approach brings the aircraft to the decision altitude at the missed approach point just 0.8 miles from the end of the runway at a 45degree angle off the runway alignment, the RNP approach uses radius-to-fix segments to gradually steer around the prohibited airspace and establishes the aircraft on a straight course aligned with the runway, 1.3 miles from the landing threshold. Additionally, the RNP approach allows for lower weather criteria (500 foot cloud ceiling and 1½ mile visibility) than the LDA approach (800 foot ceiling and 2 miles visibility) and has a simplified missed-approach ground track.

To obtain the highest level certification for these procedures, stakeholders examine aircraft equipment and operator publications. Each operator's Authorization Required (AR) documents a minimum RNP value, and this value may vary depending on aircraft configuration or operational procedures (e.g., use of flight director (FD) with or without autopilot). In some cases, operators will need to direct higher levels of automation use in order to receive approval for lower RNP tolerances. Such is the case with procedures with RNP values less than 0.3, or with Radius to Fix (RF) legs, which require the use of autopilot or FD driven by the RNAV system in all cases (FAA, 2016).

Figure 2

Ronald Reagan Washington Airport Localizer Type Direction Aid Z Runway 19 Approach Versus Area Navigation Required Navigation Performance 19 Approach



Automation Surprise and Mode Confusion

As automated aircraft systems become more complex, they accompany an inherent increase in the number of tasks the system can complete. Effectively, the human pilot must understand an increased number of modes with respect to system behavior and in which phase of flight or during which scenario each mode is most appropriate. A notable threat to safety in modern cockpits is that of human error and misinterpretation of information. This is the primary threat operators train to mitigate.

Mode confusion occurs when pilots operate with many similar system modes that may have different levels of automation and support. As a consequence of switching between systems, it is possible—particularly in periods of high stress and workload—for the pilot to confuse modes, leading to the formation of a wrong mental model, and wrong subsequent actions (Bredereke & Lankenau, 2002). This form of AS can be particularly dangerous because aircraft systems are functioning properly but the behavior of the automated system and the expectation of the pilot operating it disconnect.

When the human pilot and automated system act as separate entities, scenarios arise where one is controlling and the other is observing. A 2013 report of the performance-based operations aviation rulemaking committee/flight deck automation working group raised this concern (Nakamura, 2013). In that report, many trainers expressed concerns that their programs taught crews how to “fly” the auto-flight systems rather than how to use the automated systems to “fly” the airplane. Pilots learn automation by “watching things happen” in fixed base trainers. When they must hand fly, they are accustomed to watching things happen and reacting, rather than being proactive (Nakamura, 2013). This creates an operating climate with an elevated risk of automation surprises.

During time critical operations, mode confusion can result from even slight changes in the aircraft flight path. For example, being vectored off the assigned flight path by air traffic control, being assigned a different altitude than expected, speed or altitude crossing restrictions, or changing runway/procedure assignment can all lead to a change in the level of automation. Modern transport aircraft have seen numerous incidents and accidents, some resulting in fatalities, where an AS or mode-confusion event in the cockpit was at the forefront of the causes. Table 2 lists several examples of high-profile aviation incidents involving pilot error in automated flight decks.

Table 2

Aircraft Incidents Attributed to Mode Confusion or Automation Surprise

Flight	Location	Summary
Air India 605	Bangalore, India (1990)	Pilots failed to recognize that the aircraft was in an open (idle power) descent mode during final approach, due to inadvertently selecting the altitude knob instead of the vertical speed knob. The aircraft descended below glide path and lost airspeed, eventually crashing short of the runway (Flight Safety Foundation, 1994)
American 903	West Palm Beach, FL (1997)	During descent, the auto-throttle system disconnected, and the crew leveled off and began a turn in which the airspeed decayed to the point where the aircraft stalled. The pilots recovered after the flight controls went through a period of oscillations for 34 seconds. The aircraft lost 3,000 feet of altitude and exceeded the design limit of the vertical stabilizer (National Transportation Safety Board, 1997).
Air France 447	Atlantic Ocean	Erroneous airspeed indications caused the autopilot and auto-thrust systems to disconnect. Pilots failed to recognize the aircraft's flight-control laws, resulting in a total loss of cognitive control of the situation. The aircraft entered an aerodynamic stall and failed to recover (Bureau d'Enquetes et d'Analyses, 2012)
Asiana 214	San Francisco, CA	On final approach, the pilot manually disconnected the autopilot and moved the thrust levers to idle to capture the glidepath, causing the auto-throttle mode to change, unknown to the crew. The aircraft slowed well below target airspeed and descended below glidepath before striking a seawall short of the landing runway (National Transportation Safety Board, 2014b)
UPS 1354	Birmingham, AL (2013)	The crew failed to recognize that the approach they programmed into the flight-management computer had not sequenced properly and a discontinuity message was displayed. The aircraft crashed one mile short of the runway (National Transportation Safety Board, 2014a)

Cognitive Models of Automation Surprise and Mode Confusion

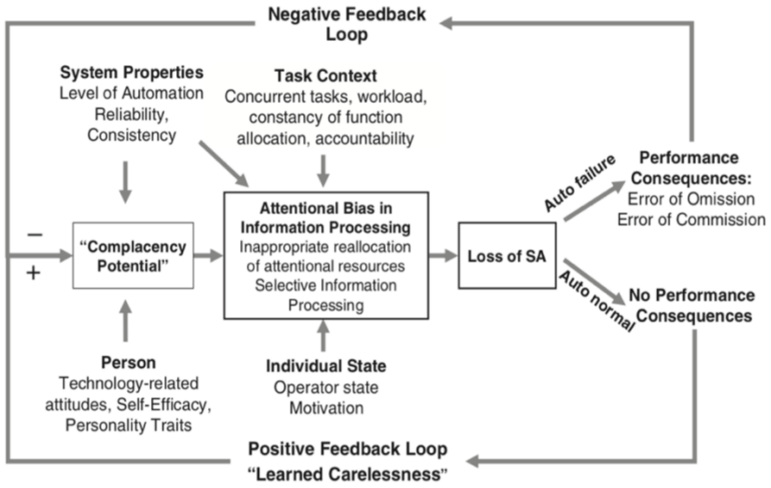
To mitigate the threat of errors in the human–machine interface, it is important to understand where and why the breakdowns occur. Dekker (2014) defined AS as “the end result of a deviation between expectation and actual system behavior, that is only discovered after the crew notices strange or unexpected behavior and that may already have led to serious consequences by that time” (Pamplona & Alves, 2015). Through the study of AS from a cognitive perspective, stakeholders provided various models used to explain such events.

Parasuraman and Manzey (2010) developed one model used to diagnose AS, focused on suboptimal human performance, now known as the integrated model of complacency and automation bias (see Figure 3). This model suggests that potential for AS increases with time if contradictory feedback is lacking, and thus, even a single instance can lead pilots to a reduction in trust in the system (Parasuraman & Manzey, 2010). The integrated model shapes the way stakeholders view AS events by attributing them to complacency or a lack of situational awareness, and pilots placing too much trust in an automated system. Thus, operators could focus training efforts on crew communication and verification of changing modes and levels of automation, as well as experiencing abnormalities and onboard alerting-systems familiarization.

Another model, known as the crew-aircraft contextual control loop, views human–machine coordination as a single joint cognitive system (see Figure 4). This model suggests a predominant cause of AS is a lack of knowledge about automation in the current operational context and trust in the automation does not necessarily diminish through contradictory feedback (Rankin et al, 2016). Therefore, the use of this model would lead toward mitigating the threat of AS by preparing crews for the unexpected, and adequately preparing pilots to cope with surprise, such as using scenarios with ambiguous and potentially conflicting information (Rankin et al., 2016).

Figure 3

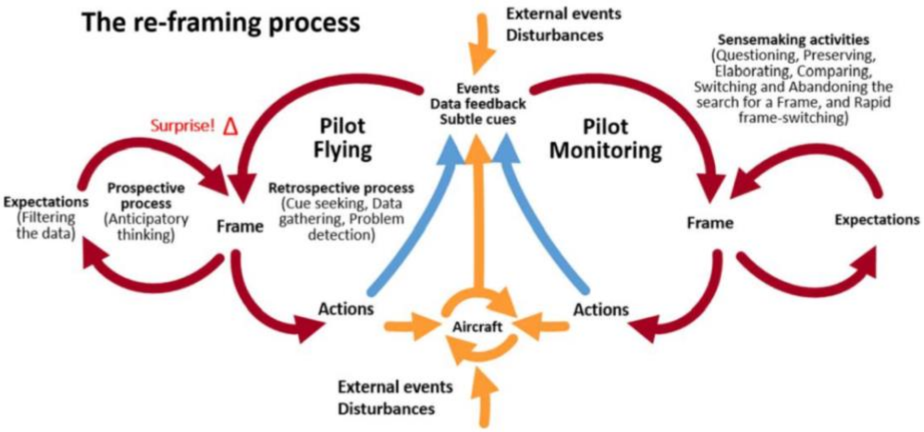
Integrated Model of Complacency and Attentional Bias



(De Boer & Dekker, 2017)

Figure 4

The Crew-Aircraft Contextual Control Loop



(De Boer & Dekker, 2017)

Another issue is operators' trust in an automated system. Opposing theories regarding cognition and collaboration between pilot and automation emphasize different outcomes. Competing theories on the effects of an AS event note different impacts. The integrated model, for example, predicts that even a single instance of contradictory feedback may lead to a considerable reduction in trust in the automated system. Hoff and Bashir (2015) found support for this theory, advocating that trust can be altered in a dynamic environment such as in a human–automation interaction. They found that "preexisting knowledge does not usually change in the course of a single interaction," however

> Once an operator begins interacting with a system, its performance can impact dynamic learned trust, which can change drastically over the course of an interaction. However, perceptions of performance depend largely on the manner in which information is presented to an operator. Thus, the design features of automation are significant, because they can indirectly influence trust by altering perceptions of system performance. (Hoff & Bashir, 2015, p. 422)

In regard to the effect of AS on trust, De Boer and Dekker found support for the sensemaking model of the crew–aircraft contextual control loop in a 2017 field study. Their results determined that in 59% of cases, pilots reported "no change" in their level of trust in an automated system, whereas on a Likert-type scale ranging from 1 to 6 (1 being "no change in trust" and 6 being "much less trust"), only 9% ranked their reduction of trust higher than 4, due to their recent AS event (De Boer & Dekker, 2017).

Another study by De Boer and Hurts (2017) examined 200 Dutch airline pilots and the relative and absolute frequency of AS during actual airline operations. The researchers found a positive correlation between operational intensity and the absolute prevalence of AS events. However, the relative frequency of AS events decreased as operational intensity increased. This is to say, the relative frequency (events per 100 flights) decreased for pilots who fly more often (in actual numbers of flights rather than flight hours). Furthermore, absolute AS prevalence decreases as pilots increase in age, experience, and rank (De Boer & Hurts, 2017). Further, the researchers found support for the sensemaking model or the crew-aircraft contextual control loop in that pilots themselves discovered 89% of AS events whereas the onboard alert system or a fellow crewmember first discovered only 11% (De Boer & Hurts, 2017).

The importance of understanding the cognitive process cannot be overstated in determining the best training methods for operators moving forward. How a pilot perceives the automated systems they are operating, and their inherent levels of trust can influence the frequency with which they are exposed to AS events. When pilots have no change in their trust in the system through AS events, such as predicted by the sensemaking model, a knowledge-based approach to training is more appropriate.

Generational Differences and Learning Styles

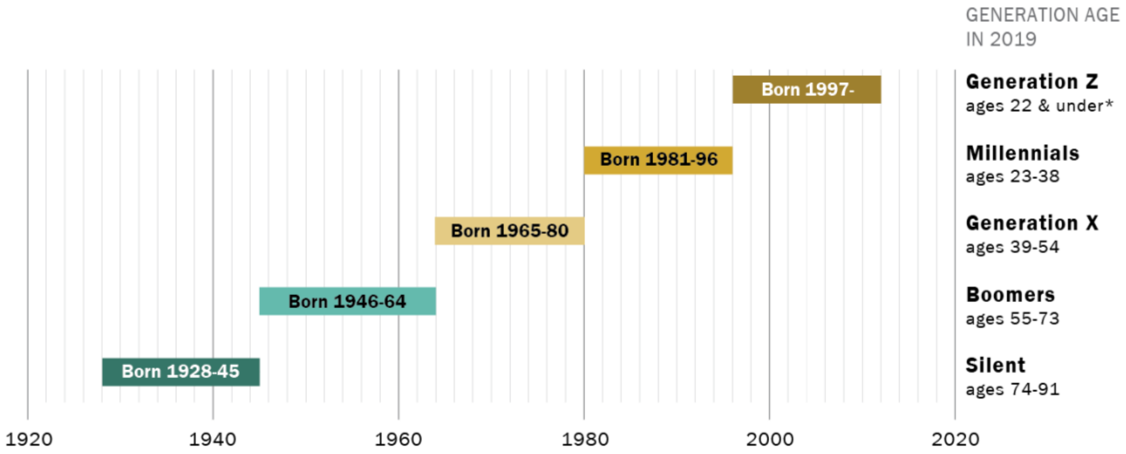
To address threats to safety and seek ways to mitigate them, first one must understand the audience. Earlier, I discussed the substantial growth projections in the industry and the corresponding demand for delivery methods to train new pilots to support that volume, and doing so to the highest standards of safety and standardization. One area requiring analysis is the target recipients of these training programs. Although the advancement of flight-deck automation can be attributed partially to the technology boom of recent decades, so, too, is the academic behaviors and perceptions of the next generation of aviators.

The Pew Research Center defined generations (see Figure 5). In the aviation industry, particularly since 2001, the pilot population at most airlines (particularly U.S. legacy carriers) was heavily represented by baby Boomers and members of Generation X. These pilots have the high levels of experience required to enter the industry, exacerbated in 2013 with the implementation of the FAA’s “1500 hour rule” (formally FAA Docket 2010-0100; FAA, 2013). The change raised the minimum-experience requirements, most notably obtaining an Airline Transport Pilot (ATP) certificate for all pilots prior to working for an air carrier under Part 121, thereby causing new pilots to take longer before entering the airline industry. In 2007, the FAA also raised the mandatory retirement age for pilots from 60 to 65, matching the International Civil Aviation Organization standard (FAA, 2007). Economic factors such as the U.S. recession during the mid-2000s also played a role in the generational classification of airline pilots. It is not my intent in this study to analyze these factors, but merely to acknowledge that the next 2 decades will differ from the last two in the demographic characteristics of airline pilots in the United States.

Currently, the overall population of U.S. airline pilots come from four generations. Pilots at the minimum age (21) must hold a restricted Airline Transport Pilot certificate, compared to those at the FAA mandated retirement age (65). Although generations are often defined slightly differently, this study used generations as defined by the Pew Research Center. As of year-end 2019, Generation Z were those aged 22 and younger. Millennials were between the ages of 23 and 38. Generation X were aged 29 to 54, and Baby Boomers were 55 to 73 (see Figure 5).

Figure 5

Generations as Defined by Pew Research Center



*No chronological endpoint has been set for this group. Generation Z age ranges vary by analysis.

PEW RESEARCH CENTER

(Dimock, 2019)

These generational boundaries have defining features. Generations are often bound by common learning styles, experiences, behaviors, perceptions, and views of the world. One focus in the educational discipline is the exposure to technology among younger generations, and how they differ from those older. For instance, Millennial and Generation Z students have always had technology integrated into their lives, whereas technology for older generations has served as an addition. Thus, as Nikirk (2012) of Tech Solutions wrote, many strategies for teaching have changed. Subtle suggested strategy tips include showing graphics and charts at the beginning of a lesson instead of leading with a textual format, as technology-savvy learners are very comfortable interpreting these products. Nikirk encouraged interactivity through games, multimedia, simulations, and virtual laboratories. Rather than a traditional “command and control” environment imposed by educators, Nikirk suggested providing clear goals and tasks to be accomplished through an overview. Nikirk wrote, “millennial students do not like to stay too long on one task,” but rather benefit more from being allowed flexibility to use different approaches and processes to arrive at solutions (Nikirk, 2012).

To expand on teaching strategies for younger generations, Simonds and Brock (2014) conducted a study using web-based survey aimed at examining student preference for types of learning activities in online courses. The multiple logistic regression analyses of students ranging in age from 21 to 70 revealed with statistical significance that

> “younger students tended to prefer live interactive methods of teaching and learning including live chats and group projects, while older students preferred to set aside time and carefully listen and take notes while watching a video of the professor lecturing.” (Simonds & Brock, 2014, p. 11)

Simmonds and Brock’s work supports previous research that pointed to younger generations embracing technology and being accustomed to interactivity, whereas older generations view these methods of innovative but may not be as comfortable with their use.

Hampton, Pearce, and Moser (2017) brought further credibility to perceptions of generational differences in education through their examination of learning styles and delivery methods in the nursing discipline. These researchers discovered similar outcomes with respect to generational contrasts. Their survey grouped online nursing students into Baby Boomer, Generation X, and Millennial categories and found correlations between age and student preferences along with distinct generational differences in preferred teaching and learning methods. The highest correlation noted was between age and online games, illustrating that the preference for use of online games decreased as students became older (Hampton et al., 2017).

In an attempt to focus on the next generation, studies have highlighted specific advanced training methods to which younger students will be most receptive. With methods centered on environment and apparatuses that are active, collaborative, and technology-rich, Bekebrede, et al. (2011) published a longitudinal study exploring the value of gaming in the formal education of university students. The study, with data collected between 2005 and 2009, sought a correlation between gaming and preference of active- or passive-learning methods. Bekebrede et al. found no difference between representatives and non-representatives of the net generation but did find a correlation between learning preferences and the use of gaming. Because people prefer active, collaborative, and technology-rich learning, gaming could have an added value in education (Bekebrede et al., 2011).

Automation Training

In recent years, airline training programs have modified their initial and continuing qualification training syllabi to highlight the importance of automation knowledge and selection. Emphasis has become known as flight-path management. Emphasis items are crew resource management, proper threat and error detection and diagnosis, and active pilot monitoring. To continue to enhance training programs for future generations of pilots, programs should use research into the cognitive aspect of human–automation interactions. The bulk of early research focused on improving system design from an engineering standpoint. However, when training pilots on their automated aircraft systems, educators can take divergent approaches. For example, relying heavily on combating complacency and attentional bias among pilots, learning objectives would skew toward systems failures and abnormalities. That is, pilots would train for varying levels of system reliability. In contrast, a training syllabus tailored more toward the crew–aircraft contextual control loop would take more of a knowledge-based approach and incorporate more manual or partially automated flight scenarios, with reliable systems.

As to pilot perception, automation training can be insufficient for line operations. A 2013 Boeing study found that in the first 6-months of flying their current type airplane, 61% of surveyed pilots reported multiple encounters of difficulty completing tasks using the FMS during line operations, whereas only 25% said they were adequately prepared. Just over 42% of pilots surveyed believed their FMS training for the type airplane they were currently flying was minimal and needed improvement or training did not adequately cover operational use. The survey also showed that operational FMS learning and "comfort" acquisition occurred online, with 42% of pilots reporting they learned the operational use of FMS during online experiences and 62% reported it took 3 to 12 months of online experience to obtain comfort with using the FMS (Holder, 2013).

Although research on how to optimize training on automated flight decks continues, the move for standardization has begun. Recently, FAA Advisory Circular 120-71B provided guidance for the design, development, implementation, evaluation, and updating of SOP, and for pilot-monitoring duties. These enhancements will begin to create standardization across the industry, laying guidelines for collaboration between operators, the FAA, and original equipment manufacturers in the construction of SOPs. Further, the circular provides strategies associated with effective auto-flight mode awareness, ranging from the inclusion of mode-change indication in procedures, to when to require verbal callouts of automation-mode statuses (FAA, 2017b).

Although many airline-training programs attempt to expose pilots to all the tools available on the flight deck in a short period of time, precedent also exists for a building block approach to learning automated systems. One case study examined a training syllabus that concentrated on developing flight path-management skills using manual flight from the outset and then gradually introduced the auto-flight systems in basic and more managed modes to achieve the same flight-path tasks (Nakamura, 2013). The researcher compared the way participants addressed off-path and ASs with a control group that had completed a more traditional training program. Results showed that the intervention group was able to anticipate, recognize, and take much more timely and appropriate interventions than the control group (Nakamura, 2013). Such an approach extends the timeline of the syllabus to focus more on line scenarios and possibly less on abnormalities.

Researchers have also thoroughly studied experiencing failures in automation. Researchers produced significant data to mitigate complacency by exposing operators to automation failures and abnormalities during initial training. The learning objective of such scenario is for pilots to show better cross-check behavior than pilots who learn with fully functioning systems and are merely warned about the potential for degraded reliability. One study focused on errors of commission in automated decision aids. Commission errors being following automatically generated recommendations that were false. The De Boer and Hurts (2017) study used automated decision aid provided advice for fault diagnosis and management. The researchers found that training in which operators are exposed to rare false advice of the automation appears to be an effective countermeasure for complacency effects (De Boer & Hurts, 2017).

Sauer et al. (2016) also examined the effects of an operator’s exposure to automation failures in training and the effect on trust, bias, diagnosis, and mode awareness. The Sauer et al. study had 45 participants experienced in training on automated systems that were either fully reliable, had automatic fault repair (faults correctly detected and diagnosed), misdiagnosed (faults detected but incorrectly diagnosed), or mis-prone (faults not detected by the system). Sauer et al. tested participants a week later; results showed a greater potential for operator error when an automated system failed to correctly diagnose a fault than when it failed to detect one. Results underlined limitations in the effectiveness of training to reduce complacency and automation bias because differences in trust levels recorded between groups after the training session disappeared after the testing session (Sauer et al., 2016).

Although proper diagnosis of automation modes and abnormalities is a critical component of pilot skill in the modern flight deck, training programs also have emphasized a balance between manual flying skills and use of part or all of the aircraft’s automation, often emphasizing error-management strategies rather than solely error detection. Research in this area includes Nikolic and Sarter’s (2007) study on diagnosis and recovery from breakdowns in pilot-automation coordination. The study examined the handling of mode errors in a 747-400 simulator from detection to recovery. The researchers gave participants three scenarios that created a high probability of automation-related disturbances including a climb performance limitation, a lateral path disturbance, and a vertical navigation-mode awareness event. Results showed that rather than detecting errors, pilots showed poor disturbance management and recovery strategies. The authors concluded that “diagnostic episodes were rare because of pilots’ knowledge gaps and time criticality. In many cases, generic inefficient recovery strategies were observed, and pilots relied on high levels of automation to manage the consequences of an error” (Nikolic & Sarter, 2007, p. 553).

In examining pilot encounters with unanticipated events on the flight deck from a cognitive standpoint, more support accrued for the crew–aircraft contextual control loop. In connecting the cognitive model to automation training suggestions, Landman and colleagues (2017) proposed a conceptual model to address unexpected events on the flight deck, compiling factors that often lead to the lack of situational awareness and AS events. Through review of previous literature and a review of four case studies in automation-induced aircraft incidents, Landman et al. contended that mental knowledge structures that were previously learned guided pilot perceptions and actions, and pilots often address unexpected situations. The authors concluded that training for events with on automation should focus on (a) increasing the supply and quality of pilot frames (e.g., through practicing a variety of situations), (b) increasing pilot-reframing skills (e.g., through the use of unpredictability in training scenarios), and (c) improving pilot metacognitive skills, learning to avoid inappropriate automatic responses to startle and surprise (Landman et al., 2017).

As air-carrier training programs continue to evolve, future pilots will formulate a core skill set and “base” emerging from contributions from the cognitive mental model and training for unexpected conditions. Past generations of pilots have typically learned their core skill set of manual control, aerodynamics, and navigation procedures in traditional airplanes with little technology; now they must transform that skill set to the modern flight deck. The next generations of pilots are being trained from the outset with more modern technology. Core piloting skills, therefore, must contain base knowledge and processes for understanding automated systems.

Pilots have increasingly fewer opportunities to manually fly their aircraft. This manual knowledge has been proven to be essential for maintaining the “stick and rudder” skills all pilots may need, and also provides a model to integrate the pilot into creating a better human–automation interaction model. Most pilots receive this manual practice in the training environment, which currently includes mandatory maneuvers as part of qualification training, such as manually controlled slow flight, manually controlled loss of reliable airspeed, and manually controlled instrument departure and arrival, as well as upset prevention and recovery training (FAA, 2017a). Although these skills are essential to sustain, the irregularity of these scenarios and the length of time between recurrent training events make this opportunity alone insufficient for most pilots. Recent flight practice is a significantly stronger predictor for fine-motor flying performance than the time period since flight school or even the total or type-specific flight experience (Haslbeck & Hoermann, 2016). Therefore, future generations will require training that not only establishes a base knowledge and skill set appropriate for modern flight decks, but also that allows them to engage their skills in various flight conditions and scenarios.

Training Delivery Methods

The design of modern flight decks incorporate the most advanced technologies available, and pilots learn their operational capabilities in a matter left largely to the operator or their training program. Typically, an air carrier’s initial qualification training syllabus lasts less than 1 month. During this time a pilot will learn aircraft systems, procedures, and line operations, while practicing various flight maneuvers. Traditionally, these phases integrated classroom instruction, written examinations, and varying levels of flight simulators. More recently, home-based and self-paced computer-based training modules (CBTs), e-brief video demonstrations, and interactive flight-management-system simulators have become more common as the emphasis in training has shifted to comprehending the aircraft's automated systems. A key focus of the aviation industry going forward will be to find innovative delivery methods that maximize pilot comprehension and reduce the amount of time spent learning new equipment.

The FAA's 2013 Flight Deck Automation Working Group's recommendations also made training methods a focus. For example, in the category of Design, Regulatory, and Training Activities, the group declared,

> The FAA and the aviation industry should investigate the use of innovative training tools and methods to expand pertinent safety related knowledge of flight crews on a continuing basis. The FAA and the aviation industry should explore incentives to encourage continued training and education beyond the minimum required by the current regulations. (as cited in Nakamura, 2013, p. 74)

The Department of Defense has been at the forefront of exploring new training methods for the next generation of pilots. In the fall of 2018, the U.S. Air Force's 711th Human Performance Wing demonstrated their Secure Live Virtual Constructive, Advanced Training Environment program's capstone at Nellis Air Force Base, NV. The program allows primarily fighter aircraft to enhance training capability by combining synthetic and real-world air combat training. In a secure environment, pilots flying live operational aircraft are able to tap into a virtual environment including a simulation of other aircraft, as well as a constructed environment consisting of computer-generated models of entities and threats (Giardina, 2018).

Also, the U.S. Air Force has begun test cohorts of their Undergraduate Pilot Training (UPT) Next program. UPT Next uses virtual-reality systems, artificial intelligence, and advanced biometrics to train students, streamlining the training pipeline while simultaneously reducing costs. The key concept of the virtual-reality devices used by students (the HTC Vive Pro Headset) is that they allow for focus on basic fundamental flying skills. Students work with instructors in a “simulator bay,” but also have their own headsets to allow for additional “sorties” on their own time, outside of the normal training syllabus. Although the curriculum uses a reduced-flying syllabus, students still receive instruction in the same aircraft as traditional UPT students to allow for the physical stresses of flying, along with gaining a sense of the feel of the aircraft. The core of the virtual-reality system is that it provides for more cognitive repetition. Furthermore, the biometrics component consists of a Zephyr “puck” students wear near their heart, designed to measure heartrate, pulse, and stress level to gauge how students are responding to a task (Losey, 2018). The artificial-intelligence piece can be used to tailor the scenario to the appropriate level of difficulty for the student. The merits of incorporating artificial intelligence into training has proven effective and economical. The next generation can be highly effective in generating motivation and other positive attitudes as well as facilitating knowledge acquisition (Shaw, 2008).

The Air Force has not yet decided on whether and to what degree their technology and training methods will be incorporated into the UPT syllabus. Still in its infancy, the program has provided data on the pilot-training process. The original cohort was able to graduate 13 of the 20 students in just 4 months, whereas the traditional UPT syllabus takes a year. Efficiency was not limited to training time. The suite consisting of 20 virtual-reality simulators costs $300,000, whereas a single legacy T-6 simulator costs $4.5 million (Losey, 2018).

Moving forward, a revolution is emerging in the methods used to train pilots, ranging from basic aerodynamics to advanced instrument procedures. As artificial intelligence and virtual reality enter the aviation industry, the goal will be to use delivery methods that maximize the retention of system knowledge and engrain cognitive motor skills and muscle memory into future generations of pilots. An integral piece of information in the formulation of these training methods will be pilots' perceptions of their automated flight-deck systems and which delivery methods maximize comprehension.

CHAPTER II

METHODOLOGY

Advancements in technology have led to a change in pilots' role on the flight deck. Operating modern aircraft creates a new set of challenges for pilots. As the industry moves forward and high demand drives the need for a highly automated operating environment, training methods will continue to evolve for future generations of pilots. This study aimed to examine pilot perceptions of automation use as well as preferred training-delivery methods and techniques, and aimed to answer whether generational differences influence these perceptions.

Population

The population for this study was airline pilots who operate aircraft under Federal Aviation Regulations part 121–Air Carrier Operations. I selected this population due to the high degree of standardization required by these types of operations and the commonality of procedures used and aircraft flown among carriers. These carriers generally operate the most advanced and most automated aircraft at the highest volume of operations and employ similar training syllabi. General aviation pilots, by contrast, operate an extremely large variety of aircraft with varying degrees of automation capabilities onboard. I excluded military pilots due to the complex nature of their operating environment, which provides too many unknown factors among sorties, providing data would likely be inconsistent. Finally, I excluded corporate pilots due to the differences in each company and aircraft type. Furthermore, I noted the unpredictability of the routes flown by corporate pilots and the lack of standardization among flight departments operating only under Part 91 in SOPs, training, and safety-management systems. Therefore, I determined that the appropriate population to answer the research questions was pilots who received training and are currently operating under FAA part 121 (2009).

Sample

The study entailed surveying pilots who are currently flying for Part 121 carriers in the United States. I selected a random convenience sample based on pilots who willingly chose to take part in the online questionnaire. I recruited participants from two popular pilot-networking websites: Airline Pilot Central–Forums, and The Pilot Network of the social media website, Facebook. Participants chose to participate in the study and provided all information voluntarily; participants received no compensation for their time. I informed participants of the nature of the study prior to beginning the questionnaire. I excluded from analysis surveys with responses that answered that they were not an active pilot flying for a Part 121 carrier. I accepted incomplete surveys and included those data in the results.

Study Design

The study was conducted using a cross-sectional design with a questionnaire serving as a one-time event for each participant, made available for 2 weeks. I used the website SurveyMonkey to create, distribute, and collect the information and data for the survey. The survey was accessible from any computer with Internet access. In addition to demographic data, a variety of questions gauged pilot perceptions of automated flight decks, levels of trust in automation, training methods, and techniques. The questionnaire included open-ended, ranking, and Likert-type scale question and response combinations.

Participants also had the opportunity to elaborate on any pertinent information they wanted to share, through a comment box at the end of the survey.

Instrumentation and Data Collection

SurveyMonkey was the online survey tool participants used to complete the survey; SurveyMonkey recorded the results. Once complete, I uploaded results to an Excel spreadsheet where I stored data and conducted statistical tests. I used the Statistical Package for the Social Sciences (SPSS) to conduct data analysis.

Analysis

I stored the data sets on a Microsoft Excel spreadsheet and used SPSS to conduct all statistical tests to report and analyze the results of the survey. To examine the research questions, I used descriptive statistics along with *t*-tests, one-way analysis of variance (ANOVA), Welch ANOVA, and Tukey and Games–Howell post hoc tests to determine if a significant relationship emerged between pilots of different generations and their levels of trust in automated aircraft systems. I set significant values for all tests at .05.

Protection of Human Subjects

The Institutional Review Board of the University of North Dakota approved the study. I informed participants of the nature and purpose of the study and each individual provided consent by voluntarily participating in the study. I did not collect participants' personally identifiable information as part of the survey, thereby keeping their identities anonymous. I deidentified any information given during open-ended answers that was specific to an individual's identity or employing air carrier. In the online survey tool, I also did not collect or store any information that could be linked to the participant. I kept all collected data anonymous, used solely for the purpose I stated for use in this study.

CHAPTER III

RESULTS

A total of 142 pilots took the survey. Twenty-one surveys were removed before analysis. Seventeen participants had their surveys removed for failing to answer “yes” to the question “Are you a current pilot for a CFR part 121 airline?” One survey failed to answer any demographic or survey questions. 3 provided demographic information only. One hundred and twenty-one surveys remained that provided data for analysis ($N = 121$). The range of the Participants ranged from 21 to 65 years old, with a mean of 39.611, and a median age 36. Three of the respondents represented Generation Z, 64 were Millennials, 39 were from Generation X, and 15 were Baby Boomers.

Table 3

Surveys Removed From Consideration and Reasons Report

Number removed	Reason
17	Participant failed to answer “yes” to the question “Are you a current pilot for a CFR part 121 airline?”
1	Participant did not answer any questions after beginning the survey
3	Participant provided only demographic data

The participants were asked to provide their age, and put into groups by generation, using their age at the time of the survey in December 2019. Other descriptive data included gender, current position, and total flight hours. Generational parameters used followed the Pew Research Center identified the ages of Generation Z (22 and younger), Millennials (ages 23–38), Generation X (ages 39–54), and Baby Boomers (ages 55–73). Descriptive data for participants from each group appears in Table 4.

Table 4

Descriptive Data of Survey Participants

Generation	*N*	Gender	Avg. age	Avg. flight hours	Current position
Generation Z	3	3 Male 0 Female	21.67	2,578	3 First Officer
Millennial	64	60 Male 4 Female	32.06	4,019	22 Captain 38 First Officer 4 Other
Generation X	39	38 Male 1 Did Not Respond	45.92	9,694	13 Captain 25 First Officer 1 Other
Baby Boomer	15	15 Male	59	23,007	13 Captain 2 First Officer

To answer the first research question on pilot perceptions of automation, participants answered three questions intended to gauge their level of "trust" in automated aircraft systems. For this data analysis, I combined Generation Z and Millennial participants into one group, and Generation X and Baby Boomer participants into another group. An independent samples t-test was performed to compare the means of the two groups. For each survey question, the five-point Likert scale used to score the responses ranged from the highest levels of trust (5) for an answer of "strongly agree" to the lowest levels of trust (1) for a response of "strongly disagree." 363 data points were collected with 201 coming from the Generation Z/Millennial group and 162 from the Generation X/Baby Boomer group. Table 5 shows the survey questions used to measure participant levels of trust in automated aircraft systems and Table 6 displays group data. Table 7 shows the results of the independent samples t-test.

Table 5

Questions Used to Measure Levels of Trust in Automation

Question number	Question
14	If the automation fails or reverts to a different mode, I understand why immediately.
16	Most of the time I have an automation surprise/mode confusion event, I find it is due to a manual entry/selection error, and not the system.
18	On-board cues and alerting systems will catch the manual input/selection errors I make.

Table 6

Group Data for Levels of Trust in Automation

Generations	*N*	Mean	Std. deviation	Std. error mean
Generation Z/Millennial	201	3.42	1.093	.077
Generation X/Baby Boomer	162	2.97	1.000	.079

Table 7

Independent Samples t-Test Results—Trust Levels in Automation

	F	Sig.	*t*	*df*	Sig. (2-tailed)	Mean difference	Std. error difference
Equal variances assumed	2.303	.130	4.039	361	.000	.449	.111
Equal variances not assumed			4.078	355.243	.000	.449	.110

The *t*-test results revealed that the group of Generation Z and Millennial pilots had significantly higher levels of trust (*M* = 121, *SD* = 14.2) in automation than pilots in the Generation X and Baby Boomer group (*M* = 2.97, *SD* = 1.000), *t*(361) = 4.039, *p* = .000.

The next series of questions assessed pilot confidence in flying with various levels of automation. Questions, 12, 13, and 15 were written so that "strongly agree" translated to the highest level of confidence in flying with various automation levels, and "strongly disagree" showed the lowest confidence level. Questions 17 and 19 were reverse scored such that "strongly disagree" was the most confident answer and "strongly agree" showed the least. Scoring of the answers was adjusted accordingly (see Table 8). I divided participant answers into four groups, by generation, and completed a one-way ANOVA.

Table 8

Questions Used to Measure Pilot Confidence in Flying With Various Levels of Automation

Question number	Question
12	I regularly use all modes of the aircraft's auto-flight system.
13	In visual meteorological conditions, I regularly disconnect one or more of the auto-flight systems more than 10 miles from the runway.
15	I am confident flying in any phase of flight with only partial or no automation engaged.
17	I avoid using certain mode(s) of the auto-flight system because I don't fully understand how it works.
19	I would prefer more time during recurrent training to hand-fly or use only partial automation procedures because I do it so rarely.

A total of 605 responses were received from questions relating to confidence levels in flying with various levels of automation engaged (*N* = 605). Of those, 15 responses came from Generation Z participants, 320 from Millennials, 195 from Generation X, and 75 from Baby Boomers. Using the 5-point scale, the mean confidence level ranged from 3.47 (Generation Z) to 3.95 (millennial). Tables 9 shows descriptive data on confidence in flying with various levels of automation subset.

Table 9

Descriptive Data for Pilot Confidence in Flying With Various Levels of Automation

Generation	*N*	Mean	Std. deviation	Std. error	95% C.I. lower bound	95% upper bound
Generation Z	15	3.47	1.125	.291	2.84	4.09
Millennial	320	3.95	1.133	.063	3.83	4.07
Generation X	195	3.72	1.169	.084	3.56	3.89
Baby Boomer	75	3.60	1.127	.130	3.34	3.86
Totals	605	3.82	1.150	.047	3.73	3.91

Table 10 shows results from Levene's test for equality of variances, testing the assumption of homogeneity of variances among the four generational groups of pilots. No significant differences emerged between the variances of the four generational groups, and the data were homogeneous.

Table 10

Levene's Test for Equality of Variances—Flying With Various Levels of Automation

	Levene statistic	*df*1	*df*2	Sig.
Based on mean	1.078	3	601	.358
Based on median	.122	3	601	.947
Based on median and with adjusted *df*	.122	3	597.150	.947
Based on trimmed mean	.982	3	601	.401

Table 11 provides the one-way ANOVA results, showing that a participant's generation had a significant impact on the pilot's confidence in flying with various levels of automation engaged *F*(3, 601) = 3.248, *p* = .022.

Table 11

ANOVA Results for Pilot Confidence in Flying With Various Levels of Automation

	Sum of squares	*df*	Mean square	*F*	Sig.
Between groups	12.741	3	4.247	3.248	.022
Within group	785.979	601	1.308		
Total	798.721	604			

Table 12 provides the Tukey's Honest Significant Difference post-hoc test, administering multiple comparisons. Results showed no significance between any two generations when flying with various levels of automation.

Table 12

Tukey's Post-Hoc Test & Multiple Comparisons for Pilot Confidence in Flying With Various Levels of Automation

(I) Generation	(J) Generation	Mean difference	Std. error	Sig.	95% C.I. lower	95% C.I. upper
Generation Z	Millennial	-.483	.302	.379	-.126	.29
	Generation X	-.256	.306	.837	-.105	.53
	Baby Boomer	-.133	.323	.976	-.97	.70
Millennial	Generation Z	.483	.302	.379	-.29	1.26
	Generation X	.227	.104	.129	-.04	.49
	Baby Boomer	.350	.147	.081	-.03	.73
Generation X	Generation Z	.256	.306	.837	-.53	1.05
	Millennial	-.227	.104	.129	-.49	.04
	Baby Boomer	.123	.155	.858	-.28	.52
Baby Boomer	Generation Z	.133	.323	.976	-.70	.97
	Millennial	-.350	.147	.081	-.73	.03
	Generation X	-.123	.155	.858	-.52	.28

Next, participants were asked a series of questions to gauge whether they perceive automation management as a tool to enhance their skill set or if they believe it degrades their overall piloting skills. The series of questions were scored and data was broken into four groups. a one-way ANOVA was then conducted to compare the data of the four groups. Questions 9, 11, and 24 such that "strongly agree" showed the highest level of perception that the pilot viewed automation management as an important skill. "Strongly disagree" showed the highest perception that emphasis on automation management degrades a pilot's overall skillset. Questions 10 and 22 were in reverse, and the scoring of the responses to these questions was adjusted accordingly. Tables 13-17 show the questions pertaining to perceptions of automation management.

Table 13

Questions Used to Measure Perception of Automation Management

Question number	Question
9	Pilots have better situational awareness flying highly automated aircraft than those flying older aircraft.
10	Piloting skills have deteriorated in recent years due to reliance on automation.
11	Automation management is more important than good hand flying skills.
22	In high workload situations, I feel that fully automated flight increases workload.
24	Overall, flying highly automated aircraft has made me a better pilot.

Table 14 provides descriptive data for the 603 responses recorded from the series of questions pertaining to whether pilots view automation management as an enhancement or a detractor to their overall skillset (*N* = 603). Of those, 15 responses came from Generation Z participants, 320 from Millennials, 195 from Generation X, and 73 from Baby Boomers. The overall mean was 3.10 and the group means ranged from 2.90 (Baby Boomer) to 3.47 (Generation Z).

Table 14

Descriptive Data for Perception of Automation Management

Generation	*N*	Mean	Std. deviation	Std. error	95% C.I. lower bound	95% upper bound
Generation Z	15	3.47	.990	.256	2.92	4.02
Millennial	320	3.22	1.210	.068	3.09	3.35
Generation X	195	2.96	1.173	.084	2.80	3.13
Baby Boomer	73	2.90	1.303	.153	2.60	3.21
Totals	603	3.10	1.211	.049	3.01	3.20

Table 15 shows results from the Levene's test for equality of variances, testing the assumption of homogeneity of variances. No significant differences emerged between the variances of the four generational groups and the data were homogeneous.

Table 15

Levene's Test for Equality of Variances—Automation Management

	Levene statistic	*df*1	*df*2	Sig.
Based on Mean	1.855	3	599	.136
Based on Median	1.776	3	599	.151
Based on Median and with adjusted *df*	1.776	3	583.818	.151
Based on trimmed mean	1.866	3	599	.134

Table 16 provides the results from the one-way ANOVA on questions relating to automation management. Which generation a pilot was from had a significant effect on how they perceived automation management as part of their overall skillset $F(3, 599) = 2.967$, $p = .031$.

Table 16

ANOVA Results for Perception of Automation Management

	Sum of squares	*df*	Mean square	*F*	Sig.
Between groups	12.920	3	4.307	2.967	.031
Within group	869.498	599	1.452		
Total	882.418	602			

Table 17 shows results of the Tukey's Honest Significant Difference post-hoc test. No significance emerged between any two generations on flying with various levels of automation engaged.

Table 17

Tukey's Post-Hoc Test & Multiple Comparisons—Perception of Automation Management

(I) Generation	(J) Generation	Mean difference	Std. error	Sig.	95% C.I. lower	95% C.I. upper
Generation Z	Millennial	.248	.318	.864	-.57	1.07
	Generation X	.503	.323	.404	-.33	1.33
	Baby Boomer	.563	.342	.353	-.32	1.44
Millennial	Generation Z	-.248	.318	.864	-1.07	.57
	Generation X	.255	.109	.093	-.03	.54
	Baby Boomer	.315	.156	.184	-.09	.72
Generation X	Generation Z	-.503	.323	.404	-1.33	.33
	Millennial	-.255	.109	.093	-.54	.03
	Baby Boomer	.060	.165	.984	-.37	.49
Baby Boomer	Generation Z	-.563	.342	.353	-1.44	.32
	Millennial	-.315	.156	.184	-.72	.09
	Generation X	-.060	.165	.984	-.49	.37

The next data set analyzed questions focused on training. Pilots responded to Questions 12 and 21 to see if they preferred to learn new aircraft procedures and maneuvers with more manual control before learning to perform using higher levels of automation. "Strongly agree" showed the highest preference for learning new maneuvers manually, and "strongly disagree" showed the lowest preference. Results recorded 242 data points. Tables 18 lists the questions used to measure pilot preference for initially learning new procedures manually. Table 19 provides descriptive data.

Table 18

Questions Used to Measure Preference for Beginning Training With Manual Control

Question number	Question
12	Pilots should learn to manually operate each system and fly each maneuver before learning to fly with automation engaged.
21	I prefer to learn a new aircraft's automated components one at a time after manually flying some basic maneuvers.

Table 19

Descriptive Data for Preference for Beginning Training With Manual Control

Generation	*N*	Mean	Std. deviation	Std. error	95% C.I. lower bound	95% upper bound
Generation Z	6	3.50	1.643	.671	1.78	5.22
Millennial	128	3.64	1.162	.103	3.44	3.84
Generation X	78	3.90	.920	.104	3.69	4.10
Baby Boomer	30	3.27	1.172	.214	2.83	3.70
Totals	242	3.67	1.114	.072	3.53	3.81

Table 20 shows Levene's test results for equality of variances. Significance emerged between variances of the data among the four generational groups.

Table 20

Levene's Test for Equality of Variances—Beginning Training With Manual Control

	Levene Statistic	*df*1	*df*2	Sig.
Based on mean	5.163	3	238	.002
Based on median	2.733	3	238	.044
Based on median and with adjusted *df*	2.733	3	219.919	.045
Based on trimmed mean	5.060	3	238	.002

Because the data were determined to be heterogeneous, a Welch statistic was administered as part of the one-way ANOVA. The Welch ANOVA showed no statistical significance between the means of the four groups in preference for learning to operate manually prior to learning maneuvers using higher levels of automation (see Tables 21 and 22).

Table 21

Welch robust test of equality of means: Beginning training with manual control

	Statistic	*df*1	*df*2	Sig.
Welch	2.537	3	21.736	.083

Table 22

ANOVA results for preference for beginning training with manual control

	Sum of squares	*df*	Mean square	*F*	Sig.
Between groups	9.196	3	3.065	2.516	.059
Within group	290.015	238	1.219		
Total	299.211	241			

Participants were then asked to rank the training methods they prefer with respect to learning auto-flight systems. They were also asked to rank the same training methods with regards to learning a new flight management system. These questions allowed participants to rank six different training delivery methods to be ranked from most effective to least effective (see table 23).

Table 24 provides Levene's test data for equality of variances, used to test the assumption of homogeneity of variances. Data from the rankings of classroom question and answer format, e-brief video demonstrations, CBT modules, and reading technical publications were all determined to be homogenous. The Levene's test showed significance in the data from individual simulator time (sig. = .028) and virtual reality rankings (sig. = .000) among the four generational groups, and the data were heterogeneous.

Table 25 provides results from the one-way ANOVA for preferred training methods, determining that a pilot's generation was a significant predictor of how they ranked a live classroom question/answer training method $F(3, 208) = 5.297$, $p = .002$.

Tukey's HSD post-hoc test indicated that the mean score for the Baby Boomer generation ($M = 1.86$, $SD = 1.329$) was significantly different from scores for Generation X ($M = 3.08$, $SD = 1.554$) and Millennial ($M = 3.04$, $SD = 1.485$) pilot groups in the category of classroom question and answer format (see Table 26). Generation Z, Millennial, and Generation X groups showed no significant differences in their means with respect to the live classroom question and answer setting. No significant differences emerged in the data between groups with regard to ranking e-brief video demonstrations, CBT modules, or reading technical publications.

Table 23

Descriptive data for preferred training methods

Training method	Generation	*N*	Mean	Std. deviation	Std. error	95% C.I. lower bound	95% C.I. upper bound
Classroom Q/A	Generation Z	6	3.00	1.897	.775	1.01	4.99
	Millennial	112	3.04	1.485	.140	2.77	3.32
	Generation X	65	3.08	1.554	.193	2.69	3.46
	Baby Boomer	29	1.86	1.329	.247	1.36	2.37
	Total	212	2.89	1.543	.106	2.68	3.10
E-brief video demonstrations	Generation Z	6	3.33	1.633	.667	1.62	5.05
	Millennial	113	3.52	1.357	.128	3.27	3.78
	Generation X	67	3.10	1.539	.188	2.73	3.48
	Baby Boomer	29	2.93	1.412	.262	2.39	3.47
	Total	215	3.31	1.440	.098	3.11	3.50
Individual simulator time	Generation Z	6	2.17	1.169	.477	.94	3.39
	Millennial	115	2.10	1.360	.127	1.85	2.36
	Generation X	69	2.68	1.702	.205	2.27	3.09
	Baby Boomer	29	2.93	1.557	.289	2.34	3.52
	Total	219	2.40	1.524	.103	2.19	2.60
CBT’s	Generation Z	6	3.50	1.049	.428	2.40	4.60
	Millennial	115	3.84	1.399	.130	3.59	4.10
	Generation X	69	3.78	1.360	.164	3.46	4.11
	Baby Boomer	29	3.97	1.239	.230	3.49	4.44
	Total	219	3.83	1.352	.091	3.65	4.01
Reading	Generation Z	6	5.17	1.602	.654	3.49	6.85
	Millennial	117	4.66	1.492	.138	4.38	4.93
	Generation X	69	4.78	1.402	.169	4.45	5.12
	Baby Boomer	29	4.03	1.401	.260	3.50	4.57
	Total	221	4.63	1.467	.099	4.43	4.82
Virtual reality	Generation Z	6	3.83	1.941	.792	1.80	5.87
	Millennial	117	3.68	1.964	.182	3.32	4.03

Training method	Generation	*N*	Mean	Std. deviation	Std. error	95% C.I. lower bound	95% C.I. upper bound
	Generation X	69	3.54	1.852	.223	3.09	3.98
	Baby Boomer	29	5.28	1.099	.204	4.86	5.69
	Total	221	3.85	1.910	.128	3.59	4.10

Table 24

Levene's Test for Equality of Variances—Training Methods

Training method		Levene statistic	*df*1	*df*2	Sig
Classroom Q/A	Based on Mean	.929	3	208	.428
	Based on Median	1.675	3	208	.173
	Based on Median and adjusted for df	1.675	3	182.645	.174
	Based on Trimmed Mean	1.000	3	208	.394
E-brief video demonstrations	Based on Mean	.426	3	211	.734
	Based on Median	.694	3	211	.556
	Based on Median and with adjusted df	.694	3	198.807	.556
	Based on Trimmed Mean	.369	3	211	.775
Individual simulator time	Based on Mean	3.103	3	215	.028
	Based on Median	2.822	3	215	.040
	Based on Median and with adjusted df	2.822	3	203.322	.040
	Based on Trimmed Mean	3.406	3	215	.019
CBTs	Based on Mean	.540	3	215	.655
	Based on Median	.332	3	215	.803
	Based on Median and with adjusted df	.332	3	211.582	.803
	Based on Trimmed Mean	.516	3	215	.672
Reading	Based on Mean	.122	3	217	.947
	Based on Median	.266	3	217	.850
	Based on Median and with adjusted df	.266	3	194.067	.850
	Based on Trimmed Mean	.126	3	217	.945

Training method		Levene statistic	*df*1	*df*2	Sig
Virtual reality	Based on Mean	13.041	3	217	.000
	Based on Median	8.873	3	217	.000
	Based on Median and with adjusted df	8.873	3	213.640	.000
	Based on Trimmed Mean	13.505	3	217	.000

Table 25

ANOVA Results for Preferred Training Methods

Training method		Sum of squares	*df*	Mean square	*F*	Sig.
Classroom Q/A	Between Groups	35.664	3	11.888	5.297	.002
	Within Groups	466.840	208	2.244		
	Total	502.505	211			
E-brief videos	Between Groups	12.081	3	4.027	1.968	.120
	Within Groups	431.659	211	2.046		
	Total	443.740				
Individual simulator time	Between Groups	24.010	3	8.003	3.567	.015
	Within Groups	482.429	215	2.244		
	Total	506.438	218			
CBTs	Between Groups	1.362	3	.454	.246	.864
	Within Group	397.387	215	1.848		
	Total	398.749	218			
Reading publications	Between Groups	13.712	3	4.571	2.157	.094
	Within Groups	459.863	217	2.119		
	Total	473.575	220			
Virtual reality	Between Groups	69.325	3	23.108	6.837	.000
	Within Groups	733.444	217	3.380		
	Total	802.769	220			

Table 26

Tukey's Post-Hoc Test & Multiple Comparisons for Preferred Training Methods

Training method	(I) Generation	(J) Generation	Mean diff.	Std. error	Sig.	95% C.I. lower	95% C.I. upper
Classroom Q/A	Generation Z	Millennial	-.045	.628	1.000	-1.67	1.58
		Generation X	-.077	.639	.999	-1.73	1.58
		Baby Boomer	1.138	.672	.330	-.60	2.88
	Millennial	Generation Z	.045	.628	1.000	-1.58	1.67
		Generation X	-.032	.234	.999	-.64	.57
		Baby Boomer	1.183	.312	.001	.37	1.99
	Generation X	Generation Z	.077	.639	.999	-1.58	1.73
		Millennial	.032	.234	.999	-.57	.64
		Baby Boomer	1.215	.335	.002	.35	2.08
	Baby Boomer	Generation Z	-1.138	.672	.330	-2.88	.60
		Millennial	-1.183	.312	.001	-1.99	-.37
		Generation X	-1.215	.335	.002	-2.08	-.35
E-brief videos	Generation Z	Millennial	-.189	.599	.989	-1.74	1.36
		Generation X	.229	.610	.982	-1.35	1.81
		Baby Boomer	.402	.641	.923	-1.26	2.06
	Millennial	Generation Z	.189	.599	.989	-1.36	1.74
		Generation X	.418	.221	.234	-.15	.99
		Baby Boomer	.591	.298	.197	-.18	1.36
	Generation X	Generation Z	-.229	.610	.982	-1.81	1.35
		Millennial	-.418	.221	.234	-.99	.15
		Baby Boomer	.173	.318	.948	-.65	1.00
	Baby Boomer	Generation Z	-.402	.641	.923	-2.06	1.26
		Millennial	-.591	.298	.197	-1.36	.18
		Generation X	-.173	.318	.948	-1.00	.65

Training method	(I) Generation	(J) Generation	Mean diff.	Std. error	Sig.	95% C.I. lower	95% C.I. upper
Individual sim. time	Generation Z	Millennial	.062	.627	1.000	-1.56	1.69
		Generation X	-.514	.638	.851	-2.17	1.14
		Baby Boomer	-.764	.672	.667	-2.50	.98
	Millennial	Generation Z	-.062	.627	1.000	-1.69	1.56
		Generation X	-.577	.228	.058	-1.17	.01
		Baby Boomer	-.827	.311	.042	-1.63	-.02
	Generation X	Generation Z	.514	.638	.851	-1.14	2.17
		Millennial	.577	.228	.058	-.01	1.17
		Baby Boomer	-.250	.332	.875	-1.11	.61
	Baby Boomer	Generation Z	.764	.672	.667	-.98	2.50
		Millennial	.827	.311	.042	.02	1.63
		Generation X	.250	.332	.875	-.61	1.11
CBTs	Generation Z	Millennial	-.343	.569	.931	-1.82	1.13
		Generation X	-.283	.579	.962	-1.78	1.22
		Baby Boomer	-466	.610	.871	-2.04	1.11
	Millennial	Generation Z	.343	.569	.931	-1.13	1.82
		Generation X	.061	.207	.991	-.48	.60
		Baby Boomer	-.122	.283	.973	-.85	.61
	Generation X	Generation Z	.283	.579	.962	-1.22	1.78
		Millennial	-.061	.207	.991	-.60	.48
		Baby Boomer	-.183	.301	.929	-.96	.60
	Baby Boomer	Generation Z	.466	.610	.871	-1.11	2.04
		Millennial	.122	.283	.973	-.61	.85
		Generation X	.183	.301	.929	-.60	.96

Training method	(I) Generation	(J) Generation	Mean diff.	Std. error	Sig.	95% C.I. lower	95% C.I. upper
Reading publications	Generation Z	Millennial	.509	.609	.838	-1.07	2.09
		Generation X	.384	.620	.926	-1.22	1.99
		Baby Boomer	1.132	.653	.309	-.56	2.82
	Millennial	Generation Z	-.509	.609	.838	-2.09	1.07
		Generation X	-.124	.221	.943	-.70	.45
		Baby Boomer	.624	.302	.168	-.16	1.41
	Generation X	Generation Z	-3.84	.620	.926	-1.99	1.22
		Millennial	.124	.221	.943	-.45	.70
		Baby Boomer	.748	.322	.096	-.09	1.58
	Baby Boomer	Generation Z	-1.132	.653	.309	-2.82	.56
		Millennial	-.624	.302	.168	-1.41	.16
		Generation X	-.748	.322	.096	-1.58	.09
Virtual reality	Generation Z	Millennial	.158	.770	.997	-1.83	2.15
		Generation X	.297	.782	.981	-1.73	2.32
		Baby Boomer	-1.443	.825	.301	-3.58	.69
	Millennial	Generation Z	-.158	.770	.997	-2.15	1.83
		Generation X	.139	.279	.959	-.58	.86
		Baby Boomer	-1.601	.381	.000	-2.59	-.61
	Generation X	Generation Z	-.297	.782	.981	-2.32	1.73
		Millennial	-.139	.279	.959	-.86	.58
		Baby Boomer	-1.740	.407	.000	-2.79	-.69
	Baby Boomer	Generation Z	1.443	.825	.301	-.69	3.58
		Millennial	1.601	.381	.000	.61	2.59
		Generation X	1.740	.407	.000	.69	2.79

Note. CBT = computer-based training.

Because the data reveled heterogeneous results associated with the individual-simulator time and virtual-reality training delivery methods, a Welch statistic was administered along with the ANOVA for these categories, as an adjusted *F* statistic was needed. The Welch ANOVA determined that pilot generation had a significant effect on how they ranked the effectiveness of the training methods of individual simulator time *F*(3, 22.616) = 3.317, *p* = .038 as well as virtual reality and interactive games *F*(3, 22.779) = 14.181, *p* = .000 (see Table 27).

Table 27

Welch Robust Test for Equality of Means (Individual Simulator Time, and Virtual Reality)

		Statistic	*df*1	*df*2	Sig.
Individual sim. time	Welch	3.317	3	22.616	.038
Virtual reality	Welch	14.181	3	22.779	.000

The Games-Howell post hoc test revealed a significantly lower preference for virtual reality training methods among Baby Boomer pilots (*M* = 5.28, *SD* = 1.099) than among Millennial (*M* = 3.68, *SD* = 1.964) and Generation X pilots (*M* = 3.54, *SD* = 1.852). Although the Welch statistic did find significance in the effect of generation on the preference for training through individual simulator time, the Games–Howell post hoc test did not find significance between any two generational groups on this training method (see Table 28).

Table 28

Games-Howell Post-Hoc Test & Multiple Comparisons for Preferred Training Methods

Training method	(I) Generation	(J) Generation	Mean diff.	Std. error	Sig.	95% C.I. lower	95% C.I. upper
Individual sim. time	Generation Z	Millennial	.062	.494	.999	-1.67	1.80
		Generation X	-.514	.519	.759	-2.23	1.21
		Baby Boomer	-.764	.558	.546	-2.50	.97
	Millennial	Generation Z	-.062	.494	.999	-1.80	1.67
		Generation X	-.577	.241	.084	-1.20	.05
		Baby Boomer	-.827	.316	.058	-1.67	.02
	Generation X	Generation Z	.514	.519	.759	-1.21	2.23
		Millennial	.577	.241	.084	-.05	1.20
		Baby Boomer	-2.50	.354	.895	-1.19	.69
	Baby Boomer	Generation Z	.764	.558	.546	-.97	2.50
		Millennial	.827	.316	.058	-.02	1.67
		Generation X	.250	.354	.895	-.69	1.19
Virtual reality	Generation Z	Millennial	.158	.813	.997	-2.73	3.05
		Generation X	.297	.823	.982	-2.58	3.17
		Baby Boomer	-1.443	.818	.376	-4.33	1.44
	Millennial	Generation Z	-.158	.813	.997	-3.05	2.73
		Generation X	.139	.288	.963	-.61	.89
		Baby Boomer	-1.601	.273	.000	-2.32	-.88
	Generation X	Generation Z	-.297	.823	.982	-3.17	2.58
		Millennial	-.139	.288	.963	-.89	.61
		Baby Boomer	-1.740	.302	.000	-2.53	-.95
	Baby Boomer	Generation Z	1.443	.818	.376	-1.44	4.33
		Millennial	1.601	.273	.000	.88	2.32
		Generation X	1.740	.302	.000	.95	2.53

CHAPTER IV

DISCUSSION

Study data showed that significance differences exist between pilots of different generations in perceptions of automation use. Pilot perceptions can shape the way they operate. Understanding these perceptions can help build more effective procedures and more efficient training syllabi.

Trust Levels in Automation

Levels of trust in automation were significantly different between the group of Generation Z and Millennial pilots compared to the group of Generation X and Baby Boomer pilots. The Generation Z/Millennial group reported .45 points per question levels, indicating higher trust in automation than their older counterparts. One question with a particularly strong indication of a pilot's trust in the design of automated systems was the question that stated, "On-board cues and alerting systems will catch the manual input/selection errors I make." This question received a negative response (disagree or strongly disagree) from 61.1% of pilots from the Generation X/Baby Boomer group compared to the Generation Z/Millennial group, where 38.8% of pilots gave negative responses. In the same trust-related survey questions was the question, "If the automation fails or reverts to a different mode, I understand why immediately." This question was geared toward gauging whether pilots attributed AS or mode confusion/reversion events more to a lack of situational awareness or to a lack of system knowledge. The Generation Z/Millennial group reported 78.1% of positive responses (agree or strongly agree) whereas 47.4% of the Generation X/Baby Boomer group answered positively.

These data can be interpreted as a split in support for the two cognitive models between generations. The higher levels of trust and the reported better understanding of automation mode reversions of the Generation Z/Millennial group support to the notion that this demographic is more susceptible to Parasuraman and Manzey's (2010) integrated model of complacency. That model suggests "complacency bias" leading to "attentional bias in information processing" and then loss of situational awareness. A lack of contradictory feedback induces a cognitive process that resembles what has been referenced as "learned carelessness" (De Boer & Dekker, 2017, p. 2). That is, the loss of situational awareness due to high levels of trust, combined with high levels of system knowledge, can lead to suboptimal human performance.

By contrast, lower levels of trust indicated in the responses from the Generation X and Baby Boomer group combined with lower levels of system understanding during mode-confusion events lends support to the Rankin et al. (2016) crew-aircraft contextual-control loop. These data match the explanation that "automation surprises in this conception are not the result of either pilot error or a cockpit designer's over-automation. Instead, they exhibit characteristics of a human-machine coordination breakdown—a kind of weakness in a distributed cognitive system" (De Boer & Dekker, 2017, p. 2). This lack of system knowledge in relation to the current operational context indicates pilots need to better train to cope with surprise or situations where they are receiving unexpected feedback.

Confidence in Flying With Various Levels of Automation

Pilot confidence in flying with various levels of automation engaged was significantly influenced by generation, however, post hoc test results revealed no significant differences between any pair of two generations of pilots. The overall trend in the data showed Millennials had the highest level of confidence in flying with various levels of automation engaged (*M* = 3.95), followed by Generation X (*M* = 3.72), Baby Boomers (*M* = 3.60), and Generation Z (*M* = 3.47). Although Generation Z pilots reported the lowest level of confidence, it is possible that this is due to the small sample size or the relatively low level of experience and time assigned to their current aircraft. Generation Z pilots' median total flight hours was 1,925, compared to 3,900 for millennial pilots, 6,200 for Generation X, and 23,500 for Baby Boomers.

With Generation Z as an outlier due to small sample size, the data trended toward younger generations of pilots showing greater confidence in flying with various levels of automation engaged. However with no significance between independent groups, more specific research is needed to determine if generations influence pilot propensity to fly with various levels and modes of automation engaged. Other variables that need to be considered are recency and type of aircraft operations flown (i.e., long-haul/widebody pilots compared to each other or domestic pilots of different generations who fly a common aircraft type). These variables were beyond the scope of this thesis but could be parameters used in future research between pilots of different generations.

Perception of Automation Management as a Skillset

Pilot perception of automation management was significantly influenced by generation. However, post hoc results revealed no significant differences between specific generations on whether pilots viewed automation management as an integral part of their overall skillset or whether it degrades from what they perceived as their core skills. Although no statistical significance emerged between any two particular generations, the data did trend toward an inverse relationship between generational age and a positive perception of automation management as an important skill for a pilot: Generation Z showed the highest scores (*M* = 3.47), followed by Millennials (*M* = 3.22), Generation X (*M* = 2.96), and finally Baby Boomers (*M* = 2.90). This trend indicated that older pilots are more inclined to view automation as a distraction that can deteriorate what they perceive to be their “core skills,” which have changed over the life of their careers. One Generation X pilot commented,

> “automation in[aircraft] makes workloads lighter and decreases stress while helping to increase [situational awareness], absolutely true. However, it will also increase a pilot’s complacency and dependency on the automation, further aiding in the deterioration of the perishable skills of actually hand flying, if all they do is solely fly by and rely upon the automation.”

Younger generations of pilots viewed that automation management is a fundamental part of a pilot’s skill set, coinciding with their higher levels of trust in such systems.

Preference for Beginning Training With Manual Control

The Welch ANOVA results revealed no significance between generations in pilot preference for initially learning new systems through manual control before proceeding to procedures and maneuvers with higher levels of automation. Including all generational groups, 66.1% of responses were positive (participants answered either “agree” or “strongly agree”), indicating that, as a whole, pilots tended to prefer manual control at the outset of training before incorporating automation into procedure and maneuver execution. For reference, follow-up Question 23 regarding desire for more manual flying during recurrent training, received just 47.9% positive responses. Although more research is needed, this trend, in conjunction with the significant results found on trust in automation, lend support to future initial qualification training syllabi that develop a pilot's flight path management skills through manual control at the outset, before introducing basic automated components. This finding supports recommendations from the FAA's Flight Deck Automation Working Group (Nakamura, 2013). Discussion then shifts to recurrent training, where emphasis on system abnormalities or scenarios that induce a high probability for AS or mode-confusion events could be more effective, after establishing higher levels of comfort and trust in system components, aligned with Sauer et al. (2016).

Automation Training Methods

The preferred training methods used by pilots to learn auto-flight and flight-management systems saw significant differences between generations.

Classroom Discussion/Lecture or Live Question and Answer Session

Baby Boomers showed a significantly stronger preference for the classroom question and answer training method compared to Generation X and Millennial pilots. Baby Boomers gave this method an average rank of 1.86. Generation Z followed (3.0), then Millennials (3.04), and Generation X (3.08). The classroom question and answer session with a seasoned line-check pilot or instructor reflected the traditional hierarchical setting with which most Generation X and Baby Boomer pilots grew up. In this study, Baby Boomer pilots gave classroom instruction the highest rank of any training methods. In contrast, the other three generations each ranked the classroom setting as their second most preferred delivery method, albeit with a much lower mean (3.053). Millennials and

Generation Z pilots continued to find value in the classroom question and answer method as each ranked it as the second most effective method, though by a small margin.

E-Brief Video Demonstrations

Experienced flight crews generally conduct e-brief video demonstrations, explaining techniques and procedures, often serving as a supplement to classroom instruction. E-brief video demonstrations are self-paced, though not interactive, and do not provide any immediate feedback to the user. Baby Boomers ranked this method their second most preferred delivery method, and it was third for Generation Z, Millennials, and Generation X. This method remained relatively constant in the ordinal context of the variables in this survey. Mean scores of this training method showed a higher score among older generations, from an average rank of 2.93 among Baby Boomers to 3.52 among Millennials. Although not statistically significant, the preference for prerecorded videos coincides with Simonds and Brock's (2014) research; they found that a group of older students responded more positively to asynchronous learning tools and found watching prerecorded video lectures helpful. The steady rank of e-brief videos should also be noted as a promotion of these videos as a supplemental training method that pilots find helpful.

Individual Simulator Time

Generation X (M = 2.68), Generation Z (M = 2.17) and Millennial (M = 2.10) pilots ranked individual simulator time in a fully functioning flight-training device as their preferred training method. The data were inconclusive in showing significance, and the Welch statistic did show significance between groups; however the Games–Howell post hoc test did not conclude significance between any two particular groups. The data do show a trend of the younger generations showing a stronger preference for this type of interactive training that offers instant feedback, such as in the case in a fully functioning training device. This method also does not rely on direct supervision from an instructor, but rather allows for trial and error by the trainee. One millennial pilot commented "CBT and hands-on training are the most effective way of learning, because you get to see what effects your inputs have on the automation system. Just seeing it in a book or on a slide do(es) nothing." Another millennial said, "After an initial explanation of how the systems work, individual practice time is helpful." These comments reflect the sentiment that younger generations are more comfortable with trial and error and seek information and feedback immediately. In contrast, Baby Boomers participants ranked this method third (*M* = 2.93), indicating they still find value in trial and error, but only after they are prepared using more thorough and traditional ground-school techniques.

Computer-Based Training Modules

CBT modules have become prevalent in many aviation training departments. They provide a condensed version of system knowledge that focuses on limitations and system functionality. This survey showed consistent results on pilot attitudes toward CBTs. Each of the generational groups ranked this training method fourth or fifth, with means only ranging between 3.50 among Generation Z and 3.97 among Baby Boomers.

Reading Publications, Aircraft Manuals, Expanded Checklists, or Technical Orders

Reading technical publications, aircraft manuals, publications, and expanded checklists is an individual form of learning that provides no feedback, but often can provide the most detail into how a system works. This delivery method ranked sixth of the six methods surveyed for Generation Z (*M* = 5.17), Millennial (*M* = 4.66), and

Generation X (*M* = 4.78) groups. Baby Boomers ranked it the fifth most effective training method (*M* = 4.03). A one-way ANOVA showed no statistical significance in the results.

Virtual Reality, Computer Simulations, or Interactive Games

Virtual-reality training systems are a relatively new and extremely interactive training method. ANOVA and post hoc tests concluded that Baby Boomers had a significantly lower preference for virtual-reality training methods than the Millennial and Generation X groups. Generation X pilots actually gave virtual-reality training systems the highest rank (*M* = 3.54), followed by Millennials (3.68) and Generation Z (3.83). Baby Boomer pilots gave this training method a staggeringly low score (*M* = 5.28), and 62.1% of data points from the Baby Boomers ranked virtual reality and interactive games as the least effective training method. It is possible that this is due to lack of exposure to virtual-reality systems and interactive games by Baby Boomer pilots.

Virtual-reality and interactive-games training is a fairly new technology in pilot training, and the Baby Boomer generation participants in this study reported an average of 5,219 flight hours in their current aircraft. It could be inferred that, as a whole, these participants have not completed an initial qualification course recently. Nonetheless, the significant results along with previous research in the field of education, showed that younger students tended to prefer live interactive methods in the classroom (Simonds & Brock, 2014).

Future Studies

This study combined aspects of previous research relating to the technological advances made in automation in modern flight decks, but was the first to consider how these factors may affect pilots of different generations. Airline-pilot training programs are a form of continuing education, and therefore need to consider the educational background and preferences of the target audience. As the educational needs of pilots entering initial qualification training change, so too, must the training methods used. Future studies should include generational emphasis on success rates of pilots using different training platforms at various stages of training. More specificity is also needed now that this study has uncovered basic differences between generational perceptions. A future study should include participants from the same air carrier and similar fleet types in order to create standardization with respect to a specific training syllabus and how it is perceived by pilots of varying generations. Based on the findings of this study, emphasis should be placed on training success of pilots using a traditional classroom setting, individual simulator time, and virtual reality systems to conduct their training. Survey methods and observations will be needed during training operations, as it will be difficult to obtain data from line operations with the anonymity of sources such as Aviation Safety Action Program (ASAP) and Flight Crew Reports (FCR). With emphasis on training systems and trust levels, future research will help curriculum writers adapt to find the combination of training tools to make available to pilots to ensure the most efficient training programs available.

Conclusion

Pilot perception of automation use is an important aspect of today’s aviation culture. Mitigating threats induced by automation is paramount to creating a safe operating environment. This study showed that those perceptions may differ among pilots of different generations. The significantly higher levels of trust displayed in automation by younger generations of pilots supports previous research in the field of education and could influence the ways procedures are written as well as how initial and re-current training is conducted. Pilots of younger generations exhibited significantly more confidence in flying with various levels of automation engaged. Referencing previous research, these factors may cause pilots to display a better understanding of system operation but also a higher susceptibility to complacency errors or loss of situational awareness.

With respect to the methods used to train on automated aircraft systems, participants ranked six of the most common methods and generational differences emerged in several. Classroom sessions remained popular, along with individual simulator time among all generations. Of the three most common self-paced supplemental study materials, e-brief demonstration videos were most popular among all generations. Virtual-reality systems and interactive games showed a significant preference from the younger generations and more research should follow regarding their effectiveness as these methods gain in popularity. Training departments should be able to use this information to modify programs and make the appropriate tools available to pilots.

APPENDIX A

Recruitment Message for Survey Participants Posted to Airline Pilot Central Forums

Fellow Pilots,

I am a graduate student currently working to complete my master's degree in aviation. As part of my research, I am conducting a survey of airline pilots who operate under FAR part 121. The focus of this survey is pilot perception of automation use. I would appreciate it if an would take the time to complete a short survey and share how you feel about the use of automation in your daily operations and the training methods used to learn these systems.

This survey is voluntary and completely anonymous. No data or personal information will be linked to any your answers. It should take approximately 7-10 minutes to complete and your participation is greatly appreciated!

If you have questions regarding this survey, feel free to contact me at ryan.leadens@und.edu.

Thank you for your time!

https://www.surveymonkey.com/r/SRN373T

APPENDIX B

Recruitment Message for Survey Participants Posted to The Pilot Network—Facebook.com

Fellow Pilots,

I am a graduate student currently working to complete my master's degree in aviation. As part of my research, I am conducting a survey of airline pilots who operate under FAR part 121. The focus of this survey is pilot perception of automation use. I would appreciate it if an would take the time to complete a short survey and share how you feel about the use of automation in your daily operations and the training methods used to learn these systems.

This survey is voluntary and completely anonymous. No data or personal information will be linked to any your answers. It should take approximately 7-10 minutes to complete and your participation is greatly appreciated!

If you have questions regarding this survey, feel free to contact me at ryan.leadens@und.edu.

Thank you for your time!

https://www.surveymonkey.com/r/SRCZ97Z

APPENDIX C

Survey Conducted Through SurveyMonkey.com

Welcome!

You have been invited to participate in a web-based survey on pilot perception of automation use. This study is being conducted for a graduate thesis at the University of North Dakota. Click next to review information about this study before beginning the survey.

Page 2

Study Information

Title of Project: Pilot Perception of Automation Use: A Generational Assessment

Principal Investigator: Ryan Leadens (ryan.leadens@und.edu)

Advisor: Mark Dusenbury (mark.dusenbury@und.edu; 701-777-5495)

Purpose of the Study: The purpose of this research study is to examine pilot perceptions of automation use, gauge trust levels in automated systems, and pilot comfort while flying with partial or no automation engaged. Also of interest will be the preferred delivery methods used during training on auto-flight systems.

Procedures: You will be asked to answer 32 questions during the survey.

Risks: There are no risks in participating in this research beyond those experienced in everyday life.

Benefits: This survey may provide a pilots a better understanding of how automation management is viewed as part of their overall skillset and enrich future training courses by finding efficiencies and preferred methods of learning new systems.

Duration: It will take approximately 10 minutes to complete the survey.

Statement of Confidentiality: The survey will not ask for any information that will identify who the responses belong to. Therefore, you can be assured your responses will be recorded anonymously. The results will be stored by surveymonkey.com and exported to Microsoft Excel and IBM Statistical Package for Social Sciences (SPSS) on the computer of the principal investigator. The data will be stored for three years after the completion of this study. The data will only be accessed by the researcher, his advisory committee, and University of North Dakota Institutional Review Board personnel. However, given that the surveys can be completed from any computer, we are unable to guarantee the security of the computer on which you choose to enter your responses. As a participant in our study, we want you to be aware that certain “key logging” software programs exist that can be used to track or capture data that you enter and/or websites that you visit.

Right to Ask Questions: The researcher conducting this study is Ryan Leadens. If you have questions, concerns, or complaints about the research please contact Ryan Leadens at ryanleadens@und.edu or Mark Dusenbury at mark.dusenbury@und.edu or 701-777-5495.

If you have questions regarding your rights as a research subject, you may contact The University of North Dakota Institutional Review Board at (701) 777-4279 or UND.irb@UND.edu. You may contact the UND IRB with problems, complaints, or concerns about the research. Please contact the UND IRB if you cannot reach research staff, or you wish to talk with someone who is an informed individual who is independent of the research team.

General information about being a research subject can be found on the Institutional Review Board website “Information for Research Participants” http://und.edu/research/resources/human-subjects/research-participants.html

Compensation: You will not receive compensation for your participation.

Voluntary Participation: You do not have to participate in this research. You can stop your participation at any time. You may refuse to participate or choose to discontinue participation at any time without penalty. You must be 18 years of age or older to participate in this study.

Completion and return of this survey implies that you have read the information in this form and consent to participate in the research.

*1. Do you want to continue to the survey?

○ Yes

○ No

Page 3

Pilot Perception of Automation Use

2. Are you a current pilot for a CFR part 121 airline?

○ Yes

○ No

3. What is your age?

4. What is your gender?

○ Male

○ Female

5. What is your current position?

○ Captain

○ First Officer

○ Other

6. Approximately how many total flight hours do you have (all aircraft types)?

7. What aircraft do you currently fly?

8. Approximately how many hours do you have in your current aircraft?

Page 4
For questions 9-24, select the answer that corresponds to your thoughts on each statement with regards to automation use.

9. Pilots have better situational awareness flying highly automated aircraft than those flying older aircraft.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

10. Piloting skills have deteriorated in recent years due to reliance on automation.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

11. Automation management is more important than good hand flying skills.

    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree

12. Pilots should learn to manually operate each system and fly each maneuver before learning to fly with automation engaged.

    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree

13. I regularly use all modes of the aircraft’s auto-flight system.

    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree

14. If the automation fails or reverts to a different mode, I understand why immediately.
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
15. In visual meteorological conditions, I regularly disconnect one or more of the auto-flight systems more than 10 miles from the runway.
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
16. Most of the time I have an automation surprise/mode confusion event, I find it is due to manual entry/selection error, and not the system.
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree

17. I am confident flying in any phase of flight with only partial or no automation engaged.
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
18. On-board cues and alerting systems will catch the manual input/selection errors I make.
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
19. I avoid using certain mode(s) of the auto-flight system because I don’t fully understand how it works.
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree

20. The initial training I received on my aircraft’s auto-flight systems prepared me for line operations.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

21. I prefer to learn a new aircraft’s automated components one at a time after manually flying some basic maneuvers.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

22. In high workload situations, I feel that fully automated flight increases workload.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

23. I would prefer more time during recurrent training to hand-fly or use only partial automation procedures because I do it so rarely.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

24. Overall, flying highly automated aircraft has made me a better pilot.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Page 5

For questions 25-30, estimate how many hours you spent during our most recent initial qualification course studying your aircraft’s auto-flight and Flight Management System (FMS) procedures using the following methods

25. Hours spent in a classroom/discussion setting or question and answer session with a seasoned pilot in type (Line Check Pilot, Instructor, etc.)

- 0-5
- 5-10
- 10-15
- 15-20
- 20+

26. Hours spent watching e-brief training videos or demonstrations (watching an experienced pilot/crew perform a task or procedure).

- o 0-5
- o 5-10
- o 10-15
- o 15-20
- o 20+

27. Hours spent using additional simulator/flight training devices on your own (executing procedures or utilizing automation features through trial and error).

- o 0-5
- o 5-10
- o 10-15
- o 15-20
- o 20+

28. Hours spent using computer based training modules to explain system operation.

- o 0-5
- o 5-10
- o 10-15
- o 15-20
- o 20+

29. Hours were spent reviewing technical orders, aircraft manuals, publications, expanded checklists, etc.

- o 0-5
- o 5-10
- o 10-15
- o 15-20
- o 20+

25. Hours spent using virtual reality, computer system simulators, or interactive games that provide real-time feedback.

- o 0-5
- o 5-10
- o 10-15
- o 15-20
- o 20+

Page 6

For questions 31-32, rank the training methods in order from most effective to least effective, with 1 being the most effective, and 6 being the least effective.

31. What method(s) of training would you find most effective with respect to learning a new aircraft's auto-flight/automation systems?

- ☐ Classroom discussion/lecture or live Q & A session led by a seasoned pilot in category (Line Check Pilot, Instructor, etc.)
- ☐ e-brief videos/demonstrations (watching an experienced crew perform each task/maneuver)
- ☐ Individual simulator time (trial and error on your own with fully functioning equipment)
- ☐ Computer Based Training modules
- ☐ Reading publications, aircraft manuals, expanded checklists, or technical orders
- ☐ Virtual reality, computer simulations, or interactive games that provide feedback

31. What method(s) of training would you find most effective with respect to learning a new Flight Management System?

- ☐ Classroom discussion/lecture or live Q & A session led by a seasoned pilot in category (Line Check Pilot, Instructor, etc.)
- ☐ e-brief videos/demonstrations (watching an experienced crew perform each task/maneuver)
- ☐ Individual simulator time (trial and error on your own with fully functioning equipment)
- ☐ Computer Based Training modules
- ☐ Reading publications, aircraft manuals, expanded checklists, or technical orders
- ☐ Virtual reality, computer simulations, or interactive games that provide feedback

33. If there are any other comments you would like to share regarding the use of automation or the training methods you prefer to use when learning new systems, please share them below.

References

Bekebrede, G., Warmelink, H. J. G., & Mayer, I. S. (2011). Reviewing the need for gaming in education to accommodate the net generation. *Computers & Education,* 57(2), 1521–1529. https://doi.org/10.1016/j.compedu.2011.02.010

Bredereke, J., & Lankenau, A. (2002, September 10–13). *A rigorous view of mode confusion: computer safety, reliability and security* [Paper presentation]. 21st International Conference, SAFECOMP 2002, Catania, Italy. https://www.researchgate.net/publication/2916206_A_Rigorous_View_of_Mode_Confusion

Bureau d'Enquetes et d'Analyses. (2012). *Final report on the accident on 1st June 2009 to the Airbus A330-203.* https://www.bea.aero/docspa/2009/f-cp090601.en/pdf/f-cp090601.en.pdf

De Boer, R., & Dekker, S. (2017). Models of automation surprise: Results of a field survey in aviation. *Safety, 3*(3), 20–31. https://doi.org/10.3390/safety3030020

De Boer, R. J., & Hurts, K. (2017). Automation surprise: Results of a field survey of Dutch pilots. *Aviation Psychology and Applied Human Factors, 7*(1), 28–41. https://doi.org/10.1027/2192-0923/a000113

Dekker, S. (2014). *The field guide to human error* (3rd ed.). CRC Press.

FAA. (2016). *FAA Advisory Circular 90-101A.* U.S. Department of Transportation. https://www.faa.gov/documentlibrary/media/advisory_circular/ac_90-101a_chg_1.pdf

Federal Aviation Administration. (2007).

Federal Aviation Administration. (2009). Part 121 pilot age limit. *Federal Register, 74*(134), 34229–34235. https://www.federalregister.gov/documents/2009/07/15/E9-16777/part-121-pilot-age-limit

Federal Aviation Administration. (2013). Pilot certification and qualification requirements for air carrier operations. *Federal Register, 78*(135), 42324–42380. https://www.gpo.gov/fdsys/pkg/FR-2013-07-15/pdf/2013-16849.pdf

Federal Aviation Administration. (2017a). *Advisory circular 120-111: Upset prevention and recovery training.* U.S. Department of Transportation. https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-111_CHG_1.pdf

Federal Aviation Administration. (2017b). *Advisory circular 120-71b: Standard operating procedures and pilot monitoring duties for flight deck crewmembers.* U.S. Department of Transportation. https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-71B.pdf

Flight Safety Foundation. (1994). Cockpit coordination, training issues pivotal in fatal approach-to-landing accident. *Accident Prevention, 51*(1), 1–8. https://flightsafety.org/ap/ap_jan94.pdf

Giardina, G. M. (2018, October 10). *SLATE demo highlights live, virtual, constructive environment for pilot training.* U.S. Air Force. https://www.af.mil/News/Article-Display/Article/1658324/slate-demo-highlights-live-virtual-constructive-environment-for-pilot-training/

Hampton, D., Pearce, P. F., & Moser, D. K. (2017). Preferred methods of learning for nursing students in an on-line degree program. *Journal of Professional Nursing, 33*(1), 27–37. https://doi.org/10.1016/j.profnurs.2016.08.004

Haslbeck, A., & Hoermann, H. J. (2016). Flying the needles: Flight deck automation erodes fine-motor flying skills among airline pilots. *Human Factors: Journal of the Human Factors and Ergonomics Society, 58*(4), 533–545. https://doi.org/10.1177/0018720816640394

Haslbeck, A., Kirchner, P., Schubert, E., & Bengler, K. (2014). A flight simulator study to evaluate manual flying skills of airline pilots. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 58*(1), 11–15. https://doi.org/10.1177/1541931214581003

Hoff, K. A., & Bashir, M. (2015). Trust in automation: Integrating empirical evidence on factors that influence trust. human factors. *Human Factors: Journal of the Human Factors and Ergonomics Society, 57*(3), 407–434. https://doi.org/10.1177/0018720814547570

Holder, B. (2013). *Airline pilot perceptions of training effectiveness.* Boeing Commercial Airplanes. https://www.scribd.com/document/231431617/Airline-Pilot-Perceptions-of-Training-Effectiveness

International Air Transport Association. (2017). *2036 forecast reveals air passengers will nearly double to 7.8 billion* (Press Release No. 55). https://www.iata.org/pressroom/pr/Pages/2017-10-24-01.aspx

Karantzavelou, V. (2018, July 25). Boeing forecasts unprecedented 20-year pilot demand as operators face pilot supply challenges. *Travel Daily News International.* https://www.traveldailynews.com/post/boeing-forecasts-unprecedented-20-year-pilot-demand-as-operators-face-pilot-supply-challenges

Landman, A., Groen, E. L., van Paassen, M. M., Bronkhorst, A. W., & Mulder, M. (2017). Dealing with unexpected events on the flight deck: A conceptual model of startle and surprise. human factors. *Human Factors: Journal of the Human Factors and Ergonomics Society*, 59(8), 1161–1172. https://doi.org/10.1177/0018720817723428

Losey, S. (2018, September 30). *The Air Force is revolutionizing the way airmen learn to be aviators.* Air Force Times. https://www.airforcetimes.com/news/your-air-force/2018/09/30/the-air-force-is-revolutionizing-the-way-airmen-learn-to-be-aviators/

De Boer, R., & Dekker, S. (2017). Models of Automation Surprise: Results of a Field Survey in Aviation. *Safety*, *3*(3), 20. https://doi.org/10.3390/safety3030020

Dimock, M. (2019). Defining generations: Where Millennials end and Generation Z begins. *Pew Research Center*, 1.

FAA. (2016). *FAA Advisory Circular 90-101A.* U.S. Department of Transportation. https://www.faa.gov/documentlibrary/media/advisory_circular/ac_90-101a_chg_1.pdf

Nakamura, Dave. (2013, September 5). *Final Report of the Performance-based operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group*.

https://www.faa.gov/aircraft/air_cert/design_approvals/human_factors/media/OUFPMS_Report.pdf

Nakamura, David, & Royce, W. (2008). Operational Benefits of Performance Based Navigation. *AeroMagazine*, 10.

Niles, R. (2019). FAA Wants Action On Declining Pilot Skills. *AvWeb*, 1.

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, *30*(3), 286–297. https://doi.org/10.1109/3468.844354

Sarter, N. B., Woods, D. D., & Billings, C. E. (1997). AUTOMATION SURPRISES. *Handbook of Human Factors & Ergonomics, second edition*, 26.

Sauer, J., Chavaillaz, A., & Wastell, D. (2016). Experience of automation failures in training: Effects on trust, automation bias, complacency and performance. *Ergonomics*, *59*(6), 767–780. https://doi.org/10.1080/00140139.2015.1094577

Nakamura, D. (2013, September 5). *Final report of the performance-based operations aviation rulemaking committee/commercial aviation safety team flight deck automation working group*. https://www.faa.gov/aircraft/air_cert/design_approvals/human_factors/media/oufpms_report.pdf

Nikirk, M. (2012). Teaching millennial students. *Education Digest, 77*(9), 41–45. http://eddigest.com

Nikolic, M. I., & Sarter, N. B. (2007). Flight deck disturbance management: A simulator study of diagnosis and recovery from breakdowns in pilot-automation coordination. *Human Factors: Journal of the Human Factors and Ergonomics Society, 49*(4), 553–563. https://doi.org/10.1518/001872007X215647

Niles, R. (2019, October 6). FAA Wants Action on Declining Pilot Skills. *AvWeb*, 1. https://www.avweb.com/aviation-news/faa-wants-action-on-declining-pilot-skills/

National Transportation Safety Board. (1997). *National Transportation Safety Board aviation accident final report: DCA97MA049*. https://reports.aviation-safety.net/1997/19970512-0_A306_N90070.pdf

National Transportation Safety Board. (2014a). *Crash during a nighttime nonprecision instrument approach to landing; United Parcel Service (ups) flight 1354, Airbus A300-600.* https://www.ntsb.gov/news/events/Documents/2014_UPS1354_BMG-Abstract.pdf

National Transportation Safety Board. (2014b). *Crash of Asiana flight 214 accident report summary.* https://www.ntsb.gov/news/events/pages/2014_Asiana_BMG-abstract.aspx

Onnasch, L., Wickens, C. D., Li, H., & Manzey, D. (2014). Human performance consequences of stages and levels of automation: An integrated meta-analysis. human factors. *Human Factors: Journal of the Human Factors and Ergonomics Society,* 56(3), 476–488. https://doi.org/10.1177/0018720813501549

Pamplona, D. A., & Alves, C. J. P. (2015). Performance comparison between conventional and PBN air navigation procedures: A case study on the route connecting Campinas airport to Santos Dumont airport. *International Journal of Science and Engineering Investigations*, *4*(38), 38–44. https://ijsei.com

Parasuraman, R., & Manzey, D. H. (2010). Complacency and bias in human use of automation: An attentional integration. *Human Factors: Journal of the Human Factors and Ergonomics Society, 52*(3), 381–410. https://doi.org/10.1177/0018720810376055

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, *30*(3), 286–297. https://doi.org/10.1109/3468.844354

Pasztor, A. (2013, November 17). Pilots rely too much on automation, panel says. *Wall Street Journal.* https://www.wsj.com/articles/pilots-rely-too-much-on-automation-panel-says-1384749188

Rankin, A., Woltjer, R., & Field, J. (2016). Sensemaking following surprise in the cockpit—A re-framing problem. *Cognition, Technology & Work, 18*(4), 623–642. https://doi.org/10.1007/s10111-016-0390-2

Sarter, N. B., Woods, D. D., & Billings, C. E. (1997). AUTOMATION SURPRISES. *Handbook of Human Factors & Ergonomics, second edition*, 26.

Sauer, J., Chavaillaz, A., & Wastell, D. (2016). Experience of automation failures in training: Effects on trust, automation bias, complacency and performance. *Ergonomics, 59*(6), 767–780. https://doi.org/10.1080/00140139.2015.1094577

Shaw, K. (2008). The application of artificial intelligence principles to teaching and training. *British Journal of Educational Technology, 39*(2), 319–323. https://doi.org/10.1111/j.1467-8535.2008.00817.x

Simonds, T., & Brock, B. (2014). Relationship between age, experience, and student preference for types of learning activities in online courses. *Journal of Educators Online, 11*(1). https://doi.org/10.9743/JEO.2014.1.3

Tarbert, 2006.