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# A Mixed Methodology Study of the Effects of Age, Touchscreens, New Technology, Automation, and Interactions on Pilot Performance

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by

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This Graduate Thesis was prepared under the direction of the candidate's Thesis Committee Chair, Clint R. "Clutch" Balog, PhD. and Graduate Thesis Committee Member Dennis A. Vincenzi, PhD., Worldwide Campus, and has been approved. It was submitted to the Department of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Science in Human Factors

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**Abstract**

This study examined the effects of age on new technology, touchscreens, automation, and the interaction with pilot performance. Touchscreens have been introduced on the aviation flight deck, combining all pilot tasks in one device in multiple locations. This study is one of the first to examine pilots, touchscreens and age. Previous studies focused on vibration, turbulence, interfaces, ergonomics, and location for incorporating them on the flight deck. This was conducted as an online survey with pilots that have worked with touchscreens in flight operations. The results found that age has an effect on pilots interacting and working with touchscreens. This effect was found with pilots age 60 and above, but there were issues within all age groups interacting and working with touchscreens. Finding the information or path was one issue, as well as layout, design and interface mentioned by all age groups. More training, using actual touchscreens or training devices exactly replicating them, and repetition were stated as ways to alleviate these issues. The amount of touch sensitivity and pressure that are needed to interact and accomplish tasks was another issue that was stated. There is a misunderstanding in some pilots about the differences in devices and touchscreens, capacitive and resistive touch, and the reasons for this. Some pilots that understood the differences still wanted a capacitive touchscreen, like personal devices. The researcher noted that completion of the entire survey from the participants increased as the age increased and the youngest age category had the highest dropout rate.

Keywords: age, touchscreens, pilot performance, cognitive, experience, expertise

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# Chapter I
# Introduction

Automation and technology advancements have relieved humans from many physically mundane tasks and increased performance and productivity. This has moved humans to working with or supervising the automation accomplishing the tasks required for the operation. There have been issues with human interactions with automation and technology due to transparency and understanding how and why the automation was accomplishing the tasks. These issues have been alleviated to a degree with the advances in technology and automation, making human interactions with automation and technology more transparent when executing tasks. The aviation environment and aircraft have significantly high levels of advanced technology and automation with which pilots must interact with in order to safely operate the aircraft. This is accomplished by completing different tasks, performance calculations, navigation inputs and communications, as well as taxiing the aircraft on the ground, taking off, flying and landing. Advancements in technology introduce newer levels of automation and avionics, continuously requiring new learning and knowledge for pilots. As humans age they undergo changes in aspects of physical and mental abilities, especially with cognitive capabilities and decline due to aging. Loss of muscle mass, mobility issues, taking more time to complete routine tasks and cognitive decline as well as other health issues occur, making interaction with automation and technology more challenging. Older humans have been seen as having difficulty with automation and technology in everyday life (Olson, O'brien, Rogers, & Charness, 2011). The assumption is that older pilots have more difficulty with automation and technology, and this will be consistent working with the newer technology that is being introduced in the aviation environment (Hardy & Parasuraman, 1997).

**Significance of the Study**

Newer technology and automation are being introduced into the aviation environment continuously, initially with airline transport category aircraft, but in recent years being incorporated in the general aviation (GA) segment. Flight decks moved from old steam gauges to glass flight decks with display units (DU's), fly-by-wire (FBW) technology and touchscreens (Stanton, Harvey, Plant, & Bolton, 2013). The advances in technology and automation increase exponentially year after year and this is seen with the changes in the aviation flight deck, telephones to cellphones and computers in the last 30-40 years. These advances and changes in technology and automation have been accompanied by interaction, transparency, ease of use and understanding issues with the pilots that have been documented and researched. During this same time period the working population has been aging. The elderly segment of the population is living well beyond retirement age, driven by increases in medical technology, better health care and living conditions (Czaja & Chin, 2007; Vanguilder & Freeman, 2011). Over the next 10-20 years, a record number of pilots will be reaching retirement age, introducing a need for new pilots from a diminishing pool of pilots (Wall & Tangel, 2018, Aug 09). This will be occurring at this high rate even with the regulations raising the age for commercial operations, Part 121, 135 and foreign equivalent operations, from mandatory retirement at age 60 to age 65 (Aerospace Medical Association, Aviation Safety Committee, Civil Aviation Safety Subcommittee, 2004; Gander & Signal, 2008). It is introducing the need for all available options including further increasing pilot retirement age and/or accepting enhancements in technology and automation that substitutes for human pilots. The older pilots started their careers with the older technology, mechanical and steam gauges, with little automation other than an autopilot that could climb, descend and hold altitude. As automation and technology increased and became more common on the flight deck, these pilots had to become accustomed to using more automation and glass flight decks that provided digital readouts of the systems, engines and data. As they are nearing the end of their careers, increasingly higher levels of automation, technology and touchscreens, are being introduced and are more common on aircraft that they are flying.

**Automation Issues**

The introduction of automation into the aviation environment occurred to reduce the accident rates, workload and give pilots relief from mundane tasks to concentrate on decision making, situational awareness (SA) and the overall flight (Berberian, Somon, Sahaï, & Gouraud, 2017; Endsley, 2017; Mosier, Skitka, Heers, & Burdic, 1998; Parasuraman & Manzey, 2010). In conjunction with this, human factors (HF) was introduced to mitigate issues with automation, design and technology that occurred. HF examined automation design and found areas that could be modified for better human interaction and understanding. It also examines human interactions within the whole system to determine better design for unanticipated events that may occur. The introduction of automation on the aviation flight deck was accompanied by bias when the pilot interacted with the automation. There were different types of bias that are associated with automation and pilots, including over reliance or lack of use. One type of bias is accepting whatever the automation was accomplishing was correct even if it was not. Another type was mistrust of the automation to correctly accomplish tasks and not use it. These different bias issues with human interaction and automation at times affected positive aircraft control and safety of flight. Confirmation bias and complacency bias occurred when pilots interacted with, and while monitoring, the automation and not understanding what it was accomplishing or not presenting accurate information (Mosier et al., 1998; Skitka, Mosier, & Burdick, 1999; Parasuraman & Manzey, 2010; Wickens, Clegg, Vieane, & Sebok, 2015). Complicating the issue of bias, it was found in research that it lasted longer in realistic settings than what was generally assumed and for less experienced participants took longer to recognized than more experienced participants (De Boer, Heems, & Hurt, 2014). Research has found issues with mode confusion, levels of automation and changes from automation to reduced or no automation and pilots having difficultly assessing when to take over for the automation (Endsley, 2017, 2018; Lee, Hwang, & Leiden, 2015). Cognitive workload of humans increase as the difficulty of tasks increases, but cognitive workload is variable based on the levels of automation (Evans & Fendley, 2017).

Engaging automation relieves the pilots from manually flying and their roles switch from active flying to monitoring the automation. This is to ensure that the automation is working as required, correctly and continues to as programmed by the pilots. Topical examination is that this is a simple and easy task; however, this is not the case causing pilot monitoring issues during all phases of flight (Sumwalt, Cross, & Lessard, 2015). The pilots experience difficulties actively engaging with the automation and can be confused or overwhelmed by the amount of information presented (Dadashi, Golightly, & Sharples, 2017). Lack of engagement with the automation and being presented with too much information that is not easily processed leads to the pilots being out of the loop (Berberian et al., 2017; Dehais, Causse, Vachon, & Tremblay, 2012). Actively engaging and monitoring the automation for issues or malfunctions to occur increases stress on pilots (Warm, Parasuraman, & Matthews, 2008). When issues or malfunctions occur, the pilots are startled or surprised by these issues and are slow to react and respond to them (Landman, Groen, van Paassen, Bronkhorst, & Mulder, 2017).

### Aged Related Cognitive Issues and Advanced Technology

Cognitive performance often differs between humans and they are affected differently when subjected to high cognitive workload, performance and mental states (McKendrick, Feest, Harwood, and Falcone, 2019). Humans, as they age, are affected by cognitive decline, reduced workload ability and decreased reaction times that have been researched and documented (Bishop, Lu, & Yankner, 2010; Murman, 2015). Initial research recognized decline in memory and further research using neuroimaging found aging differences with neural function and structure that affect memory performance (Park & Festini, 2017). There are differences between normal aging and pathology that can be seen with behavioral and neural measurements (Park & Festini, 2017). Exacerbating normal cognitive decline in humans are medical issues that increase cognitive decline in older humans. This is seen in hypertension increasing cognitive decline as well as increasing the risk of stroke (Gifford et al., 2013). Hypertension also contributes to dementia and decreasing vascular integrity and other cognitive issues relating to the brain in older humans (Gifford et al., 2013). Additional research found that cardiovascular risk factors have subtle effects on the brain and contribute to cognitive decline (Boots et al., 2019). In the aviation environment, cardiovascular risk factors have been associated with slower psychomotor performance and cognitive slowing (Hardy, Satz, D'Elia, & Uchiyama, 2007). The Federal Aviation Administration enacted the 60-year age limit for pilots flying Part 121 air carrier operations, and some other foreign commercial operators, due to these types of risks (Aerospace Medical Association, Aviation Safety Committee, Civil Aviation Safety Subcommittee, 2004). The International Civil Aviation Organization (ICAO) enacted this rule for member states and was adopted by the Joint Aviation Authorities (JAA) and then by the European Union Aviation Safety Agency (EASA) for European member countries (Aerospace Medical Association, Aviation Safety Committee, Civil Aviation Safety Subcommittee, 2004). Not all ICAO member states followed the age 60 rule and had other ages or no age limit at all (Aerospace Medical

Association, Aviation Safety Committee, Civil Aviation Safety Subcommittee, 2004). The pilot shortage that was developing across the globe, as well as research examining the age 60 rule, had the age for mandatory retirement raised to age 65 (Aerospace Medical Association, Aviation Safety Committee, Civil Aviation Safety Subcommittee, 2004; Gander & Signal, 2008). This applies to only one crewmember in a two-crew operation in commercial, FAA Part 121, 135, and foreign airline equivalent operations (Gander & Signal, 2008). One of these research studies was an examination of West and East European helicopter pilots cardiometabolic risk markers found no indication of worsening conditions (Bauer, Nowak, & Herbig, 2018). Research of Swedish military pilots and Swedish pilots and cabin employees with Scandinavian Airlines found low overall cardiovascular mortality in all groups that extended beyond retirement age (Linnersjö, Brodin, Andersson, Alfredsson, & Hammar, 2011). Examining in flight incapacitation, one reason cited for limiting pilots age, found that it is extremely rare overall and rarer at age 60 and above (Huster, Müller, Prohn, Nowak, & Herbig, 2014). A healthier lifestyle, exercise, mental stimulation, better nutrition and controlling medical conditions and managing stress lead to a lessening of cognitive decline in older humans (Murman, 2015).

The effects of aging and cognition have been found to affect the use of technology, computers and the internet (Czaja et al., 2006). Research has found that there is a divide between age groups, as well as minority groups, and computer usage (Czaja et al., 2006). The general consensus and belief are that older humans are not willing to use technology and computers, but the available data does not support this consensus opinion (Czaja & Chin, 2007). It indicates that anxiety, design transparency, ease of use and self-efficacy are the root cause for the lack of computer use (Czaja et al., 2006; Czaja & Chin, 2007). Age related cognitive abilities affect the use of computers, as well as the design of the computers and interfaces, but competence and prior experiences affects performance (Czaja et al., 2006; Czaja & Chin, 2007). Aging and cognition affect how pilots react to automation, monitoring issues, and malfunctions, especially in aviation critical areas of spatial learning, inductive reasoning and learning (Vanguilder & Freeman, 2011). There are differences in cognitive perception and motor skills in older pilots compared to younger pilots (Hardy & Parasuraman, 1997). These differences occur gradually over time and there are no differences in delayed recall of verbal material, immediate recall of visual-spatial material or verbal instructions (Hardy et al., 2007). This is a normal occurrence during the aging process in all humans but can be offset through different types of training. Older humans showed increased attention, controlled processing, alertness, delayed and immediate recall of pictures and were less distracted with training using non action video games (Ballesteros et al., 2014). Changes in the executive control functions, memory updating, shifting, and resistance to interference, through training in older humans occurs with first person shooting games (Green & Bavelier, 2003; Green & Bavelier, 2006).

**Experience and Expertise**

The aging process is balanced by experience and expertise, particularly in the aviation environment, working with automation and decision-making (Morrow et al, 2008). Experience and expertise have been widely recognized in many industries and in the aviation environment it is defined by flight time, time on specific airframes and overall experience. Newly hired pilots start their flying from the right seat and move to the left seat and in command of the flight in Part 121 and Part 135 airline and regional airline operations. The left seat is usually designated as the captain and the right seat is designated as the first officer. Starting in the right seat and moving to the left is a normal occurrence and true in military operations, Part 135 companies, and Part 91 corporate operations and some GA operations. Most GA aircraft are flown by owners for personal and pleasure use as well as instruction in learning to fly and achieving a private pilot's license. With additional instruction pilots can achieve an instrument rating, commercial pilot's license, multiengine rating and eventually, with enough time, qualify for an airline transport pilot's license. Generally, there have been two paths to airline and corporate operations, one through entering the military and qualifying for the aviation segment, then gaining employment once they leave the military. The other way is learning to fly and earning additional ratings and license and instructors' ratings, then teaching other pilots. With additional flight time, gaining employment in a Part 135 operation or regional operations and then with time and experience, airline or corporate operations. Along each step the pilot will start out in the right seat and with time and experience eventually transition to the left seat in command of the flight. At the corporate level once this occurs, operations with multiple captains will rotate flight segments one seat to the other, each flying from the left seat. In airline, regional and some 135 companies the captain is always in the left seat and the first officer in the right seat. They still rotate flight segments, but the first officer flies his segments from the right seat.

Early research examining experience and expertise was not accompanied by statistical analysis and included non-pilots in the study when examining age related cognitive decline (Hardy & Parasuraman, 1997). The studies that concentrated on pilots and included statistical analysis found lower accident rates based on the experience and expertise of older pilots (Hardy & Parasuraman, 1997). There have been research studies conducted stating expertise plays a role in aviation and with automation (Morrow et al., 2008; Strauch, 2017). Expertise has been shown to be advantageous over non expertise in the aviation environment and there is a slight advantage for expert older pilot over other expert pilots (Morrow et al., 2008). Integrating pilots' levels of expertise within training with automation to enhance and elevate that expertise leads to a reduction of pilot's automation interaction errors (Strauch, 2017). Two types of automation, information and decisions, were examined to determine if different levels of cognition ability are needed to develop expertise (Jipp, 2016). It was found that different cognitive abilities are needed to develop expertise with different types of automation (Jipp, 2016). Also, that decision automation and information automation have different effects on developing expertise (Jipp, 2016). Examining pilot's decision making found that expertise and experienced pilots use cognitive abilities to make more accurate, faster problem solving, risk management and decision making when responding to cues associated with issues and malfunctions (Schriver, Morrow, Wickens, & Talleur, 2008). Expert pilots analyze the failures for relevant cues in decision making and are more capable of examining highly diagnostic cues than less expert pilots (Schriver et al., 2008). In the GA environment, data shows that experienced pilots are less likely to be involved in accidents due to pilot error (Bazargan & Guzhva, 2011). However, these pilots are involved in more fatal accidents possibly due to the demanding conditions in which they fly in (Bazargan & Guzhva, 2011). The lower crash rate for experienced pilots is replicated in the Part 135 on demand charter environment where all the pilots are paid professionals (Li, Baker, Grabowski, Qiang, & Rebok, 2002).

The aviation industry along with other industries, medical and computer technology, has embraced high levels of technology and automation as have the humans involved in these industries and have become accustomed to this fact. As this new technology and automation is introduced, the interaction with the pilots becomes more intuitive, easier to use and understanding of what is being accomplished (Stanton et al., 2013). For the last 30-40 years, the industrial part of the world and to a lesser extent other parts of the world, have been introduced to technology and automation in normal life in computers, cellphones, touchscreens in many business applications, banks, medical offices, etc. (Gao & Sun, 2015). Interaction with humans and automation and technology has become commonplace, easier and more user friendly. Pilots have grown up using this technology and automation and its incorporation in the flight deck is natural and should not have any adverse consequences with interaction between the pilots and the automation and technology.

**Touchscreens**

The advances in technology and automation filtering into the GA aircraft, particularly private business jets, are paralleling what has been and is in commercial transport jets. One of these advances is the introduction of touchscreen controllers on the flight deck (Products in the news, 2014). The most common touchscreen device has been used as an electronic flight bag for aviation charts, like the Jeppesen service with approach charts, standard instrument departures (SID's), standard terminal arrival route (STAR) and taxi diagrams. There have been tablets specifically designed for this purpose and has spread to iPads that contain the manufacturer's documentation, Aircraft Flight Manual (AFM), Operating Manual (OM), etc. Tablets and iPads have removed the need for having paper charts and paper manuals on board, reducing weight and alleviating the need for bulky paper charts and manuals to be stored on the flight deck. Using touchscreens was seen to not be suitable for the aviation flight deck due to the environment, motion, turbulence and the issue of interacting with the touchscreens (Coutts et al., 2019; Dodd et al., 2014). In the environment of the flight deck more errors, issues with interacting with the tabs or buttons and location were not conducive to the early technology (Dodd et al., 2014). Constant vibration and changing turbulence conditions were a concern that had to be addressed with touchscreen interactions in the aviation environment (Orphanides & Nam, 2017; van Zon, Borst, Pool, & van Paassen, 2019). Advances in touchscreens interfaces, tabs, feedback, buttons and interface interaction during all conditions have enabled them to be introduced and become standard on the flight deck (Cockburn et al., 2017; Cockburn et al., 2019; Orphanides & Nam, 2017). Touchscreens are easier to navigate and weigh less than the traditional flight management systems and multi-function control and display units (MCDU's) that they are replacing (Cockburn et al., 2019). Touchscreens are more easily navigated, designed for bracing in turbulent conditions and the use of tabs and buttons are more interactive and intuitive for selection (Coutts et al., 2019). These devices are a logical step and continuation of the advance of technology and automation in the aviation flight environment and mirror the technology and automation that is and has become prevalent in normal life. The touchscreen incorporates aviation tasks, FMS, communications, navigation and performance into one device rather than being in several devices in separate dedicated places (van Zon et al., 2019). Touchscreens are placed in the areas of separate FMS, MCDU's and communication devices and have all the needed tasks and functions incorporated as one in all those locations increasing SA and reducing cognitive workload (Coutts et al., 2019; van Zon, et al., 2019). Pilots have all the tasks that they must complete in one device and can access and work with that data quicker (Avsar, Fischer, & Rodden, 2016). Additional improvement in SA is the location of multiple touchscreens, replacing FMS and MCDU's located between the pilots behind the throttle quadrant, and one for each pilot located in their forward view adjacent the flight deck displays (Avsar et al., 2016; Dodd et al., 2014). The Gulfstream G500/G600 has only touchscreens on the flight deck located in four places (Figure 1).

Figure 1. Gulfstream G500 flight deck

**Statement of the Problem**

New technology, automation and touchscreens are being incorporated with new and emerging aircraft that are being introduced. Pilots have to learn new concepts and ways to accomplish tasks that are different from previous flight deck technology. Learning that occurs will be at different rates from pilot to pilot and there may be differences from age group to age group. If there are differences with the age of pilots and if it specifically affects their ability to interact, work and be competent with new technology, automation and touchscreens, there may be specific reasons related to age. This study examined pilot age and touchscreens to see if there are differences and if they may be cognitive, age related, or issues with technology and automation, or there may be no differences in age groups.

**Purpose Statement**

The examination of pilots' performance interaction and working with, and understanding of touchscreens and their workload and, specifically, if this is affected by age. It examined the time to acquire the knowledge that is required to become competent in the use of the new technology and automation in the aviation flight deck. Human aging issues have been well documented for the past 30-40 years, especially in the aviation industry, with statistical data, and intellectual and memory decline was first recognized by a Greek philosopher in 700 BC (Park & Festini, 2017). Normal decline in cognition is a fact for humans and can be recognized in work and everyday life, even in the aviation environment. Experience and expertise are used by older humans to counter normal cognitive decline. When medical or pathology issues occur, they compound cognitive decline and this affects work and life, and this is seen with cardiovascular conditions increasing cognitive slowing (Boots et al., 2019; Gifford et al., 2013; Hardy et al., 2007). Cognitive issues in the aviation environment have been well documented over the same time period, 30-40 years, and the FAA enacted the age 60 rule for commercial 121 operators, that pilots could no longer fly upon reaching 60. The reasoning for this is that cognitive and medical issues, incapacitation being the primary reason, would occur during flight, endangering the flight and passengers (Huster et al., 2014). This is being disproved through research and advances in the medical field, as well as better nutrition and physical health with evidence that a decrease in cognitive decline occurs with a healthy lifestyle (Murman, 2015). Over the last 30-40 years, the advances in automation and technology on the flight deck have grown appreciably, creating a highly automated technical environment. This has not occurred in a vacuum without any pilots involved and they have learned how to operate, complete tasks and work in this environment. The introduction of touchscreens has made this easier, combining all pilot tasks into one device, spread in several locations within the flight deck (Coutts et al., 2019; van Zon, et al., 2019). More transparent technology and automation, working with advanced technology, greater health and nutrition and better medical care have mitigated many issues related to normal aging. The study examined the data from the participants that may provide evidence that there is no specific issue with interaction and working with touchscreens and pilots age.

**Research Question and Hypotheses**

In this study, pilot's interaction, understanding and working with new technology, automation and touchscreens will be examined by age.

$H_0$: The effects of age will have no effect on pilot's acquiring, learning, and gaining knowledge of touchscreen technology and other automation technology.

$H_1$: The effects of age will have an effect on pilot's acquiring, learning, and gaining knowledge of touchscreen technology and other automation technology.

$H_0$: The effects of age will have no effect on pilot's interaction and working with touchscreen technology and other automation technology.

$H_1$: The effects of age will have an effect on the pilot's interaction and working with touchscreen technology and other automation technology.

A questionnaire composed of qualitative and quantitative questions provided the data to determine the hypotheses.

**Delimitations**

The present study was conducted by the researcher for a thesis degree in a time limited course and with little financial resources available. This provided a limited time to complete the required IRB documentation and approval, publishing the material, acquiring participation, collecting the data, analyzing and publishing the results. The questionnaire was published on esurveycreator.com, online service and limits the pilots to those that will have easy internet access to participant in the present study. These pilots were required to have experience with touchscreens in flight operations and be open to all commercial operators, FAR Part 121 and 135, GA pilots, and military pilots. The pilots were divided into three separate age groups: 18 years old up to but not including 40 years old, 40 years old up to but not including 60 years old, and 60 years old and older. Pilots will not be just from the United States, but across the worldwide aviation environment in all aircraft that use touchscreens. The present study grouped the pilots specifically by age and will not group by gender.

**Limitations and Assumptions**

The present study had potential limitation with the researcher's previous knowledge and working with a portion of the potential participants. This prior knowledge may be from previous FAA flying experiences, or recent instructing or examining FAA, EASA, or Qatar pilots. The assumption is older humans have more difficulty with technology and use it less than younger humans (Olson et al., 2011). This extends into all facets of life and work and with the introduction of touchscreens into the aviation environment it is a common remark when discussing pilot's interaction with them. This study examined that assumption in the aviation environment and with touchscreen technology.

# Chapter II
# Review of the Relevant Literature

## Introduction

This study examined if age affects interaction and working with, and the understanding of, touchscreens on the aviation flight deck. Different areas of previous research were needed to be consulted to provide the background and foundation to conduct this study. Research in these areas has been peer reviewed, well documented and published by numerous authors. For this study these areas that were examined are automation issues in aviation, cognitive issues, experience and expertise of humans, and touchscreens. Automation was examined in a wide range of different issues that have occurred with pilots and their interactions with it. Cognitive issues with aging and technology were examined and included medical conditions. Differences in older and younger pilots' interaction with automation and their cognition were examined. In conjunction, this included examining experience and expertise of older pilots and how that affects interaction with automation and technology. Touchscreen introduction in the aviation flight deck needed to address issues of pilot interaction and ergonomics, as well as vibration and turbulence.

The research on automation issues examined different bias with pilot interaction and automation as well as the difficulties understanding what the automation was accomplishing. Additionally, pilot's interaction with automation was affected by the levels of automation that are employed and their monitoring of the automation to accomplish the tasks that are programmed. Pilots were found to be not in sync with the automation, out of the loop, subjected to stress monitoring for faults or malfunctions and then startled and surprised when issues did arise.

Cognitive aging issues and technology research was examined for this study. As humans age, cognitive decline is part of the natural aging process and a normal occurrence. Medical issues and disease can accelerate and exacerbate cognitive decline, leading to difficulties in accomplishing routine tasks. Interaction with technology and automation can become increasingly difficult with these issues, especially as newer, more advanced products are introduced. Addressing medical issues with better nutrition, physical and mental activity, stress relief and medication was shown to mitigate cognitive decline. Research suggested that training older adults can have the potential to slow and counter some areas of cognitive decline. Training and better technology design was suggested to increase older adults' interaction with technology and mitigate the anxiety and lower self-efficacy they feel when using technology.

**Automation Research**

Berberian, Somon, Sahaï, and Gouraud (2017) examined the topic of human automation interaction in everyday life, making it easier and faster, but also contributing to issues with the automation. The authors examine performance issues that humans have with automation that have been reoccurring for decades. Humans are often left out-of-the-loop with the automation, not understanding it or what it is accomplishing and the authors suggest using neuroergonomic concepts to understand why this occurs and how to counter it. The authors state that it is not only important to examine how humans interact with automation, but why they interact that way. The study cited issues with humans monitoring automation, the vigilance needed and their minds wandering while accomplishing these tasks, as well as design issues that exacerbate them. Countering these issues, the authors suggest using neuroscience to address how human cognitive performance interacts with automation. Their research was conducted in a laboratory on a small scale that they believe could be assessed in other settings. One aspect of automation design has been to provide as much information as possible to the users. This can give the users all the information needed, but under abnormal conditions, high stress and workload, this can be overwhelming.

With the issue of information overload, Dadashi, Golightly, and Sharples (2017) examine how the information is presented with alarms in dynamic environments. Information overload, in this setting, occurs when too much information is presented at the initial stages of alarms. This overwhelms humans and slows the process of reacting and diagnosing the alarm from the information that has been presented. The authors found more errors occurred from this information overload, but receiving more information later had more of an effect on their ability to diagnose and handle the alarms. Participants in this study were trained novices and not operational experts and a simulated environment was used limiting the study, but providing a framework on the design of information presented to users. Human interaction with automation has had different effects with users either relying and trusting the automation when it was not doing what was expected, not monitoring the automation in the tasks programmed for it, confusion on what the automation was accomplishing and the automation providing incorrect or no alerts during abnormal conditions or with malfunctions.

This human interaction with automation can also lead to cognitive workload issues and this is examined by Evans and Fendley (2017). The authors discuss that system design and interface improvements have been accomplished to offset the complexity of the automation as it increases. Better interfaces, however, can hide the complexity of the system, information overload and user workload can still increase and their performance degrades. With the use of eye tracking to examine physiological state, the authors found that cognitive workload is variable based on the levels of the automation and it was highest during increased fixation rates, long run times and a low level of automation. Fixation rate was found to be different with different levels of automation and that using physiology was a good way to rate cognitive workload of the users.

Bias with humans and automation has been examined extensively and in terms of instant analysis and reaction, De Boer, Heems, and Hurt (2014) studied the duration of it in a simulator scenario with pilots. The study found that bias in trusting the automation lasted longer than anticipated in scenarios when participants were not presented with a displayed malfunction message. The pilots accepted that the automation was accomplishing the tasks rather than the visual cues that it was not because there was no posted warning alerting them there was an issue. It was also found that less experienced pilots took longer than experienced pilots to realize that the automation was not performing as required (De Boer et al., 2014). This contradicts accepted material on pilots' time to recognize malfunctions and the need for error management training for pilots in scenarios of surprise, conflicting information and ambiguity. This would provide the pilots the ability to respond during these conditions instead of using error prevention.

In a study on human automation interactions Dehais, Causse, Vachon, and Tremblay (2012) examine the subject from the standpoint of human error, conflict, cognitive degradation and psychological aspects. The study suggests that conflict reduced the participants' ability to focus attention on all information that was being presented and limited their focus to information showing an abnormal issue. This was in line with eye tracking studies on display of information. Participants that could focus attention continuously on all displays of information performed better in reacting to issues than those participants that focused solely on one display. A limiting factor was that the study had 13 participants, possibly limiting the robustness of the study, but asks the question of how to solve and respond to the issue of conflict in human automation interactions, particularly when the automation is rigid in system design that fails to react to conflict with human operators.

In two articles, Endsley (2017, 2018) examines the issue of levels of automation, human interaction and automation interfaces. Stating that the early findings on automation issues affecting SA and putting humans OOTL with the automation. The author defines an aspect of automation that as it becomes more robust and is capable of doing more things it leaves the human user unaware of how that is being accomplished and exactly when the human user needs to assume control over the automation when it is not accomplishing what it was programmed to accomplish. This issue becomes more important, as the author states, as automation moves towards semiautonomous and autonomous modes that are occurring with newer systems. Determining the appropriate levels of automation with human interaction will enable the appropriate SA for the humans.

In the study by Landman, Groen, van Paassen, Bronkhorst, and Mulder (2017), the authors examined pilots' actions and reactions with startle and surprise on the flight deck and outlined the differences between the two. Startle is a physiological reaction, fast and brief, to a sudden event while surprise is a cognitive and emotional response to a sudden, unexpected event. These two reactions have previously been seen as similar, especially in the aviation environment. The authors highlight the differences and propose different practical and unpredictable training scenarios for pilots that emphasize these differences. It was suggested that this would provide the pilots with the ability to better analyze and respond to startle and surprise and the differences between the two. Lee, Hwang, and Leiden (2015) examine mode confusion on the flight deck that occurs between pilots and automation when the automation is doing something the pilot does not expect, or if the pilot is unsure what the automation is accomplishing. The pilots may respond to the automation improperly or not at all, increasing the odds of an incident or accident. Incorporating modes confusion detection systems would enhance safety of flight and the ability to inform the pilots that it is occurring. The authors examine mode confusion detection algorithms and found that they work offline and do not provide that data to the pilots, but store that data for examination after the flight. The study proposes an algorithm for mode confusion between the pilots and the automation that would work in real time, enhancing the safety of flight.

Automation bias, mode confusion and decision making on newer glass flight decks is examined in an early study by Mosier, Skitka, Heers, and Burdic (1998). The authors found that the pilots that internalized accountability were less likely to have automation bias and respond to anomalies and verified that the task was being accomplished. It was found that the pilots were not utilizing information cues and were biased to the automation and automation aids. Future studies on automation, automation bias and training pilots and crews for automation bias were discussed. Conducting further examination of automation bias and decision making, the authors Skitka, Mosier, and Burdick (1999) proposed that automation decision making aids led to two types of errors by humans interacting with automation. The two errors stated in the study are commission errors and omission errors. Humans taking no action to the automation and allowing the automation to accomplish the wrong task are allowing commission errors to occur. They are biased that the automation is correct and accomplishing the task as required when information or evidence is showing that this is not correct. Errors of omission occur when humans, presented with non-automated indications of an issue, fail to act because they have not been presented with an automation aid advising them of an issue.

Parasuraman and Manzey (2010) examine complacency and bias with human interaction and automation determining while different they share commonalities with underlying attentional processes in humans. Their study proposes ways to mitigate complacency and bias with automation systems as well as improving feedback and situational conditions. The study highlights the concept of individual differences and the need for improvements in training and design of systems to account for this in automation. Examining the difficulties associated with ineffective monitoring by pilots was accomplished by Sumwalt, Cross, and Lessard (2015). The authors examined data from the National Aeronautics and Space Administration's (NASA) Aviation Safety Reporting System (ASRS) for incidents and accidents associated with monitoring issues. Monitoring issues were found in all phases of flight with the most significant in high rates of descent, but the greatest potential for risk was during the approach phase. The cases involving accidents occurred because detection of errors did not occur before the accident. Improper and lack of workload management, planning ahead and staying ahead of the current situation, as well as not understanding what the automation is telling the pilots, was found throughout the reports. Incorporating automation was accomplished to relieve humans of mundane manual tasks, monitoring the automation and focus on cognitive tasks. Monitoring the automation was assumed to be relatively easy, consume little cognitive workload or effort and not stimulating.

Warm, Parasuraman, and Matthews (2008) examined task monitoring and found that being constantly vigilant was cognitively hard and stressful. Vigilance is difficult to maintain at a constant rate and extended time period and had not been accounted for in the design of automated systems. Further, it increases stress and worry and over time leads to a lessening of vigilance with task engagement. More stress and distress are added as the task requirements change or increase, reducing performance. Examining automation alerting systems and their imperfections and how this impacts automation bias and complacency were examined by Wickens, Clegg, Vieane, and Sebok (2015). The authors found that automation alerting systems that gave false alerts or no alerts at all contributed to higher levels of bias and complacency in humans responding to them. Alerts that were correct had more accurate diagnosis and responses and lower workload by the participants. Automation alerts that give wrong information was found to be worse than when there was no alert given by the automation.

This review of the literature on different types and ways that human interaction with automation issues that have occurred is the basis for designers to develop systems that are more user friendly and transparent. Automation relieves humans in all industries, particularly pilots in aviation, of mundane tasks to focus on the overall aspects of the operation. This has been accomplished with some caveats and issues that the articles examined. Additionally, different levels of automation, from low to high, has provided different issues for the user to interact with. This has ranged from different bias, to mode confusion, monitoring issues and not knowing when the automation needs to be removed and the pilot to assume command. Newer technology, automation and touchscreens are being introduced to make human interaction with automation to alleviate and potentially eliminate those issues.

**Aged Related Cognitive Issues and Advanced Technology**

Bishop, Lu, and Yankner (2010) examine human aging, cognitive decline and Alzheimer's and the underlying reasons that occur in the brain naturally and pathologically. The authors discuss loss of memory during aging and that this is not accompanied by loss of neurons. Also, protein accumulation in the brain during aging or pathologically can lead to Alzheimer's and that currently the only known way to increase lifespan is through reduced caloric intake. The authors state aging of the brain is the main cause of cognitive decline and neurodegeneration. In a study by Boots et al. (2019) cardiovascular disease risk factors were found to contribute to cognitive issues in older adults. The study found subtle changes in brain connectivity that was detectable with subtle changes in cognitive functions due to cardiovascular disease risk factors. The authors stated that further research in longitudinal studies that could replicate their findings have the potential to find biomarkers, identify them and use them in prevention studies against cognitive decline and Alzheimer's disease.

Gifford et al. (2013) examined the issue of blood pressure and hypertension contributing to cognitive issues, dementia and Alzheimer's disease in older adults. The authors suggested that the association between cognitive decline and blood pressure may have several pathological processes contributing to that and that may occur prior to signs showing cognitive decline. One limitation to the study is the authors' used only studies in English that had been peer reviewed, thus inducing a Type 1 error of positive publication bias. In an examination of medical risks in older pilots, Huster, Müller, Prohn, Nowak, and Herbig (2014) found that inflight incapacitation of pilots, caused by medical issues, is extremely rare. Pilots have a better overall life expectancy, health and less likely to have cardiovascular issues, than the general population. In an examination of Part 135 operations Li, Baker, Grabowski, Qiang, and Rebok (2002) found no significant differences in the ages of pilots and crash risk. This included a segment of pilots that were age 60-64, that had a very small number of crashes, three, and some were caused by aircraft malfunctions. They also found that pilots, as a whole, with more than 5,000 hours of flight time had significantly lower crash rates than less experienced pilots.

A study conducted in Sweden of Swedish Armed Forces and Scandinavian flying personnel by Linnersjö, Brodin, Andersson, Alfredsson, and Hammar (2011) found low mortality and myocardial infarction occurrences of the participants during their working careers and into retirement. They stated that this was most likely due to the better health and physical wellbeing of the participants, although this lasted well into retirement beyond. Medical records, as well as requirements in Sweden to account for cause of death, provided strong evidence to the study and the results. There were no deaths nor acute myocardial infarction incidents on a follow up of the study. In an examination of European helicopter operations Bauer, Nowak, and Herbig (2018) found no cardiometabolic risk in helicopter pilots of Eastern and Western European descent as they approached the enforced age 60 rule for single pilot operations. This was in line with previous studies as the authors stated and they too recommended that individualized examination rather than one rule applying to everyone be adopted. As they stated, a limitation to the study was the age 60 rule itself as there were no participants or samples to examine beyond that age for risk factors.

Aerospace Medical Association, Aviation Safety Committee, Civil Aviation Safety Subcommittee (2004) defines the issue of the age 60 rule, the reasons and the studies behind the rule's adoption. Stated in the article is that aging and pilot performance is not well understood and could not easily be explained providing reasoning to enforce the rule. The article continues and examines the options of raising the age beyond 60 stating that there are few cases of pilot incapacitation causing accidents. Current medical examination of pilots at six-month periods was adequate if removing the age 60 rule was done or further medical tests could be examined and conducted if the age was raised above 60. Gander and Signal (2008) examine age, and shift work and fatigue and a proposal by the International Labor Organization to force older workers to retire or move from night shift to day shift because of fatigue and sleep related issues. It is stated that the age 60 rule in aviation had been arbitrary and recently raised to age 65. This applies to only one crewmember in a two-crew operation in commercial operations, but not all ICAO member states had adopted the age 60 rule. Various age limits had been adopted by member states, up to 65 years of age, a few with no age limit, and that few inflight incapacitations had led to accidents. The authors stated that fatigue and sleep related issues were more of a risk with shift work and pilots' readiness and fitness for flight. Additionally, there were few studies, data or research that has been conducted on fatigue and sleep related issues in other industries. The authors state that each industry needs to find comprehensive approaches that are tailored for that industry.

McKendrick, Feest, Harwood, and Falcone (2019) discuss mental workload, cognition and human interactions with automation and machine learning. The authors state that with intelligent systems and automation that humans' mental workload must be accounted for and communicated to the system. Instilling individual differences when accounting for workload in supervised learning systems should provide the best performance across all the conditions that were tested. Functional and structural changes of the brain occur with change in cognitive function because of aging in older adults was examined by Murman (2015). The author discusses this as a normal occurrence of aging, states that this may be mitigated by a healthier lifestyle of diet, exercise and mental stimulation. Reducing stress and excessive toxins as well as treating cardiovascular issues, depression, diabetes and sleep issues would also contribute to mitigating cognitive issues related to aging. Park and Festini (2017) study memory and aging theories from the past 50 years of research. They discuss aging and cognitive issues that occur and different advances that have occurred. Vanguilder and Freeman (2011) examine the changes in the hippocampal neuroproteome that occurs with aging and cognitive decline and the ability to counter that with exercise. Cognitive decline does not represent a “more aged” phenotype, but rather is associated with specific changes that occur in addition to age-related alterations.

Ballesteros et al. (2014) examined increasing some aspects of cognition in older adults through training with non-action video games. It was found that training did improve in recall of family pictures, alertness, were less distracted and better reaction time. The study did not examine whether these improvements are maintained nor if they can be duplicated with everyday tasks. It does suggest that older adults’ brains do retain some neurocognitive plasticity that can be enhanced with training, but this does not happen with executive functioning, including memory updating, shifting and resistance to interference. This is in contrast to several other studies which suggested that there were improvements in executive functioning with training. Further examination in this area was one of the suggestions by the authors. In two studies by Green and Bavelier (2003, 2006) the authors found that action video games enhances the visual spatial attention of the participants that were trained using them compared to control groups.

This was shown to be accomplished by increasing attentional resources and facilitating visual selective attention of the participants.

In an examination of technology and computer usage Czaja et al. (2006) found that although computer usage in older adults is increasing, there is still a divide between older adults and younger adults. The authors also stated that less educated and minority sectors have less computer usage. The segment of older adults in the study reported computer usage higher than in other studies that was stated as these participants in the study were more educated and healthier. The older adults in the study reporting less computer usage reported more anxiety and lower self-efficacy with computers and technology. The study stated that lower technology usage is not necessarily due to cognitive issues and age-related decline, but self-efficacy, attitudinal and sociodemographic factors.

Czaja and Chin (2007) examined the access to technology from aging and found differences in technology and computer usage in older and younger adults. The authors found that issues with overall design of input devices, screens, complex operating procedures and commands and a lack of adequate instructional support and training as a cause of this differences. The designers do not take into account age related issues that older adults have, do not understand age related decline issues and do not consider older adults as users of technology or their products. Olson, O'brien, Rogers, and Charness (2011) examined computer usage in older adults and found that there have been increases in the number of older adults using technology and computers. Older adults are still less likely to interact and be familiar with software and computer systems, using email and mice and keyboards, basic input devices. It was suggested that older adults are slower to adopt and more selective in using technology rather than a generalized aversion. In the area of healthcare, the use of technology is higher by older adults, due to more need, and their internet usage seeks information in this area as well as community and travel. Younger adults' internet usage is across a wide setting of domains and they are more familiar with all types of technology and computer devices, systems and software.

The articles examine age related cognitive decline, the age 60 rule and technology. There is age related decline for all humans and while can be classified as such across age groups, it is different for each individual. Cognitive decline is affected by different medical issues such as blood pressure, other cardiovascular issues, dementia and Alzheimer's. Physical fitness, a healthy lifestyle and addressing medical issues mitigates aging issues and cognitive decline. The age 60 rule was arbitrary, as well as raising it to 65, and had very little research and data to verify its adoption. Research that has been accomplished has provided data that refutes its existence. Additional research has shown that it is possible to reduce cognitive decline in some areas with training in older adults. Other research has shown that it is technology design and interaction, rather than age itself, that contributes to the issue that older adults refrain from using technology. This can lead older adults to feel anxiety and unable to work with technology when it is the technology presentation and interaction that is the issue. The designers of technology and automation and interfaces can reasonably be seen as the factors behind human interaction issues particularly older adults.

**Experience and Expertise**

Bazargan and Guzhva (2011) examined data from the NTSB for pilot error and fatal accidents by gender, age and experience in the GA sector. The authors found that there was no significant difference in pilot error accident rates between the genders. They did find that female pilots are less likely to be involved in fatal accidents than male pilots, but over time these differences lessened. Experienced pilots were found to be less likely to be involved in an accident cause by pilot error, but that pilots older than 60 were found to be involved in more fatal accidents and accidents caused by pilot error. Experienced pilots were found to have more fatal accidents, but this was attributed to their flying environment. An examination of age and expertise on pilot decision making was the focus of Morrow et al. (2008). This was accomplished with complex and simple flight situations with older and younger expert and novice pilots. Expert pilots were found to have better decision making during the scenarios, but this occurred primarily in older pilots. There were no apparent cognitive ability issues between older and younger pilots and age had little impact on expert pilots' decision making. Recall of information and details that occurred during the scenarios were subject to age related differences for older expert and older novice pilots as they had more difficulty than younger pilots.

Hardy and Parasuraman (1997) studied older pilots' cognition and flight performance and found that experience does provide some benefit with performance. It does not offset aging decline in basic cognitive tasks, but older pilots compensate for this by the way they accomplish tasks using processes that have been less affected with loss. Hardy, Satz, D'Elia, and Uchiyama (2007) examined pilot performance and cognition by age, individually and by group. They found that there are cognitive decline issues that occur with the age of pilots, but with delayed recognition of verbal material and the immediate recall of verbal and visual-spatial material there was no age-related differences. Also, as a group there are no age-related differences that occur up to 62 years of age. Individual differences in cognition occurred across all age groups and in a sizeable number of individual pilots stated as outliers. Outliers occurred in greater numbers in older pilots starting at 40 years of age. Cognitive decline in older pilots was suggested to be related to cardiovascular issues rather than age itself and several studies were cited. Exercise was suggested as a way to mitigate cognitive slowing in older pilots and reducing their response risks during flight tasks.

Expertise differences in pilot decision making was examined by Schriver, Morrow, Wickens, and Talleur (2008) during a simulator experiment requiring action and response to a failure. Expert pilots had better decision making and response to the failures, but pilots that were less expert were found to have better response to a single cue failure. The authors stated that this may be because the expert pilots were examining the failure for further cues or more complex failure. This was shown with more complex failures that the expert pilots responded to better than less expert pilots. The authors suggested that training of pilots with less expertise, with varying cues and more explicit training, could speed their decision-making growth.

Jipp (2016) suggests that expertise can be developed with automation, but that it requires different cognitive abilities depending on the automation configuration. He examined two types of automation, decision and information, and found differences between them when developing expertise. With the decision automation there was an increase in the need to process the information that was being provided during initial development of expertise. With the information automation there can be an increase in the workload of working memory during the latter part of developing expertise. He suggested that human interaction and automation investigations should be considered from the users' cognitive abilities and levels of expertise. Proposing a system of automation expertise training Strauch (2017) suggests that automation be integrated with the expected levels of expertise of pilots on the aviation flight deck. He also states that designers, training developers, regulators, and companies need to work together to design the proper automation integration with the user's level of expertise. This is to counter the fact that designers continue to design and produce automation that exceeds the end users' level of understanding and capability to operate those systems and that training resources and time is not enough for end users to develop the level of expertise that is needed with the automation.

Experience and expertise are discussed in these articles and show that is a way to offset some cognitive decline due to aging in pilots. This is limited to certain areas of cognition and does not apply to all areas. Cognitive decline and issues can be classified to age groups, but there are variances within the age groups by individuals. The articles mirror the data and findings in the articles on age related cognitive issues and advanced technology. Cognitive decline is individualized, different for each individual, and cannot be seen the same for everyone per age category. Age group related differences were found not to occur up to the age of 62 and that differences were by individual. Age related decline is compensated for by older pilots by how they perform the tasks.

**Touchscreens**

Prior to incorporating touchscreens on the aviation flight deck, there were issues that needed to be addressed and some of those were with interfaces, tabs, buttons, ergonomics, vibration and turbulence. Avsar, Fischer, and Rodden (2016) conducted a mixed method examination on the design of touchscreens on the flight deck. The authors provided background on the progress of technology and changes on the flight deck from the beginning of aviation. In this study they used simulation, field trials, lab experiments and a questionnaire to analyze pilot tasks with tabs, buttons and the ability of stabilizing the hand in turbulence and vibration for proper selections. These difficulties were confirmed, but there were a number of countermeasures found that offset those difficulties. The authors established a framework on touchscreens on the flight deck and provided support for incorporating the technology.

In two separate studies by Cockburn et al. (2017) and Cockburn et al. (2019) the authors examined touchscreens designs under vibration and turbulence conditions. One of the findings was that bezel edges manufactured as part of the touchscreen design provided stabilization for interaction during vibration and turbulent conditions. The bezel edges were found to provide a way for the participants to stabilize their hands when interacting under these conditions. With larger touchscreens the ability for stabilization was greatly reduced and did not work as the size of the touchscreens increased. Location of touchscreens were examined and it was suggested that further research been accomplished to determine an appropriate tradeoff between vibration errors and ergonomic requirements. Advantages of incorporating touchscreens was the ability to locate across the flight deck, while reducing the space needed and the weight of touchscreens compared to current devices. The touchscreen interfaces can be updated without having to be replaced with a newer design and at greatly reduced costs.

In Coutts et al. (2019) ergonomic aspects of touchscreens, locations, positions on the aviation flight deck, and the interaction during vibrations and turbulent conditions were examined. The study confirmed the results of Cockburn et al. (2017) and Dodd et al. (2014) with performance issues during vibration and turbulent conditions. The authors concluded that touchscreen incorporation was viable and that target size and spacing be the guiding issue. Also, that the correct location as well as angle to reduce ergonomic issues with viewing and interaction, especially during vibration and turbulent conditions. The study also stated that touchscreens have the potential to increase SA by their intuitive interactions and flexibility in displaying tasks while reducing cognitive workload. Touchscreens and turbulence were examined in Dodd et al. (2014) by tab and button targets, size and spacing. It was found that smaller target size, particularly in turbulent conditions, contributed to more pilot errors making selections, had higher fatigue, especially in the forearm areas and higher workload. It was also found pilots committed more errors with capacitive type touchscreens compared to resistive type touchscreens. The suggested reason for this was the possibility of inadvertent touches with capacitive due to the sensitivity, where resistive touchscreens require a level of force to complete the touching task. Design for touchscreens on the aviation flight deck was suggested to take into account the target size and spacing, particularly when subjected to turbulent conditions, thus reducing workload and errors. The authors also stated that the incorporation of touchscreens would reduce weight and save costs.

Gao and Sun (2015) highlighted the advances and the widespread introduction of touchscreen technology in everyday life. The study examined the usability of touchscreen gestures with older and younger adults and found that when the button sizes were above 15.9 by 9.0 millimeters, both groups had higher satisfaction and better performance with devices. For older adults, using gestures that required more than one finger produced more errors and was more difficult. Older adults in the study reported more satisfaction with touchscreen gestures and touchscreens than the younger adults. Orphanides and Nam (2017) examined quantitative studies of touchscreens across different areas of use, including aircraft, and that the studies focused on touchscreen technology, the population using them and the environment and settings that implementation was occurring in. Their findings stated that implementation of touchscreens needed to take into account the end users, environment, inputs and interfaces for the tasks to be accomplished. It was also stated that touchscreens with an inclusive design may be a more viable device for all users. Older adults are faster on touchscreen keypads compared to physical keypads. An inclusive input method would alleviate older adults' issues with divided attention by providing a good match between task and input method.

The online article Products in the News (2014) from Newstex Trade & Industry Blogs talks about the introduction of Honeywell touchscreens in the new Gulfstream corporate jets as part of the new Symmetry flight deck that includes the Honeywell Epic avionics package. This implementation of touchscreen technology lists the advantages of weight savings, incorporation of tasks into one device making it more user friendly and intuitive. It mentions that pilots are used to working and interacting with touchscreen technology in normal everyday life. These are areas of touchscreen technology that the journal articles, listed in this study, examined and researched. The data and results found from those articles have been incorporated in ways with the Honeywell touchscreens. Stanton, Harvey, Plant, and Bolton (2013) examined four types of interfaces on the aviation flight deck, touchscreens, trackball, touch pad and rotary control. These devices had selections for drop down menus and interactive for the testing and audio and non-audio inputs for feedback. The authors tracked errors for each of the devices and menus and found the touchscreen better for overall performance. A drawback was the location of the touchscreens in the study which contributed to ergonomic issues that the authors state needs to be addressed for incorporation production aircraft. Audio feedback had no effect on performance from the participants in the tests that were conducted. The authors found that not one of the four input interfaces performed well across all the scenarios, but the touchscreen performed better over the variables compared to the others.

In the article by van Zon, Borst, Pool, and van Paassen (2019) the authors examined three different devices interfaces for navigation and FMS input. Referencing several articles over the past decades, the authors state that touchscreens have the ability to reduce cognitive workload due to intuitive interaction and task flexibility display. The interfaces were touchscreens, keyboard select for a control display unit (CDU) and rotary knobs for the mode control panel (MCP) examining pilot inputs using the tradeoff of movement time and speed and accuracy, Fitts' Law, analyzing how touchscreen technology compares to current technology. It was found that the touchscreen technology was outperformed by the CDU and the MCP, but this was during a single task for navigation for the study, and not navigation tasks that would take place in a realistic setting. Selection of keys on the CDU were kept low to reduce the cognitive effort during the study. The CDU was found to require a much harder input and the touchscreen did not provide feedback when task buttons were selected. The MCP had good results with selections with non-dominant hands. The authors stated that the cognitive effort to locate keys on the CDU during realistic settings and complex selection would have the potential to increase the cognitive effort.

The articles highlight the issues that needed to be addressed with touchscreen technology in the areas of vibration, turbulence and ergonomic issues with location, tab and button sizes. Touchscreens offer improvements in different areas on the flight deck while increasing performance and reducing cognitive workload. They offer one device that incorporates all pilot tasks, being able to have several across the flight deck, at reduced weight and reduced cost when updating the devices. Touchscreen technology, similar to smart phones, tablets and iPads, are an extension of mass, every day technology, that humans use across the world. Interactions with touchscreens are no more difficult than operating a smart phone, tablet or iPad and minimize the learning curve with flight deck avionics.

**Additional Information**

The article in the Wall Street Journal by Wall and Tangel (2018, Aug 09) highlight the pilot shortage that is occurring across the globe with an estimated 635,000 pilots needed in the next two decades for the airlines alone. The pilot shortage is occurring in the military sector at the same time even with cutbacks in the military ranks. The military sector was a huge supply of pilots for the airlines and this curtailment is forcing the airlines to require and train pilots themselves along with hiring from the commuter sector. Yoshikawa, Weisner, Kalil, and Way (2008) examine the differences in qualitative and quantitative research and how it is used in developmental sciences. They show how each method is used in conducting research and the advantages, disadvantages of using either or both in studies. They find that using a mixed methods approach can provide greater detail and richness and areas where their use is more suited.

The book by Creswell and Poth (2018) examines five different approaches to qualitative studies that are used. These are narrative research, phenomenology, grounded theory, ethnography, and case study and each have specific areas and procedures that can be used when conducting qualitative studies. The book is in its fourth edition and includes a new author alongside Creswell to provide an additional point of view in examining the differences between the five approaches. This is to provide researchers and potential researchers data on the differences, characteristics, multiple ways to approach qualitative research and each approach. Chigbu (2010) discusses qualitative studies adding historical studies to the five approaches that Creswell and Poth (2018) examine in their book. His study looks at hypotheses in qualitative research and how they can be used from conversations, discussions and narratives. He examines the difficulties of correctly framing and examining hypotheses in qualitative studies to portray the scientific data gained into the proper scientific knowledge. Chigbu (2010) presents, in his study, how to conduct qualitative research with hypotheses accurately and how to confirm or deny the hypotheses.

The use of Likert type scales, uses, advantages and disadvantages are examined in four separate studies. In the article by Finstad (2010) the researcher discusses the use of five-point and seven-point Likert scale questions. His research states that seven-point scale questions provide more in-depth analysis than five-point scales. His study found that participants interpolate in five-point scale answers and may not accurately provide their real responses. He stated that the results of his study provide data that seven-point Likert questions provide the participants the ability to fully refine their answers between selections. Sullivan and Artino (2013) examine five-point and seven-point Likert scales and their viability to use parametric analysis instead of nonparametric analysis in ordinal data. The authors state that parametric tests can be used in the analysis of Likert scale answers. They state the research from another study that parametric tests can be used Likert scales and are more robust, generally, than nonparametric tests. They do recommend that this be planned by researchers and discussed in the Methods section the explanation and reasoning to present the data in this manner.

In two separate studies, the author Hartley (2013) and Hartley and Betts (2010) examine the format of Likert questions and prevalence of being worded negative to positive for ranking. Hartley (2013) provides data that Likert type scales are regularly used in psychological studies, most use four-point or five-point, and most start from negative, zero or one, and end with a positive, five or seven. He notes that some ask more than one item in a question and this causes difficulties for participants in trying to answer the questions. He also noted that higher scores may be obtained when the questions were worded from positive to negative instead of negative to positive. This confirmed the previous work of Hartley and Betts (2010) that showed positive to negative scored Likert type scales had higher ratings than when compared to three other worded versions. The authors noted that this conclusion was only from their study and not from others or similar studies that have been done. They suggest asking participants what they are thinking when completing different versions of the same questionnaire so that they can be aware of any inconsistencies.

**Summary**

The literature review of the articles examined the areas of human interaction and automation, age related cognitive issues and advanced technology, experience and expertise, touchscreens and an article on the pilot shortage and one on mixed methods research. These articles provided the data for the background and proposed research for this study. The articles from human interaction and automation from the aviation environment highlights the issues that have occurred from different types of bias, complacency, mode confusion, transparency, and monitoring. Automation, as it becomes more complex and able to accomplish more tasks, can become more difficult to interact with and understand what is occurring. Humans can be out of the loop with the automation becoming unaware of what it is accomplishing, how it is accomplishing tasks and lose SA. Imperfect automation, automation that gives erroneous alerts or no alerts when it should, further complicates human interaction. This leads to the humans being surprised or startled by the automation, particularly when issues or malfunctions occur. These articles suggest ways to counter human interaction and automation particularly in the design of automation, interfaces and more transparency. Addressing these areas in the ways that the authors of the articles suggest can ease and simplify human interaction and automation.

Age related cognitive issues and cognitive decline is a normal occurrence that happens to humans as they get older. Older adults' interactions and working with advanced technology has been an issue that has been examined and researched. The background articles on both of these topics provides evidence of these issues. The articles examine these issues and find a number of reasons for cognitive decline in older adults being caused by medical issues, especially cardiovascular issues, lack of exercise, nutrition and stress. There is age related cognitive decline, but this is affected by medical and physical conditions that exacerbate the decline. This decline can be seen in groups by age, but it is individualized per older adult and not set at a particular rate for the group. Data and information provided in the articles also suggest that pilots are aware of these issues and are in better physical condition. Having to maintain acceptable physical condition to maintain their ability to fly by thorough physical examinations every six months is the main reason for this. Articles examine the initial age 60 requirement and found little supporting data of inflight pilot incapacitation, the main reason for this rule and one of the reasons for raising the age to 65. The articles examining older adults and technology suggest a number or reasons for their lower rate use than younger adults. Issues with interfaces, design not tailored to older adults as well as anxiety and self-efficacy are suggested as the reasons for the lower rates of use by older adults. The general perception that older adults cannot or do not want to deal with technology has some basis, but the articles provide the data and reasons for this. The articles also suggest that training may mitigate age related decline and could possibly provide increases in some cognitive ability.

Examining the articles on experience and expertise with pilots suggest that this has a positive effect on pilots as they age. Experience and expertise can mitigate pilot performance issues as they age as well as offset cognitive decline that affects them as they age. This is limited in certain areas and not across all cognition. Also, this is individualized per pilot on the exact extent of cognitive decline. Cognitive decline does occur with pilot age groups, but is not at a fixed rate of decline for all in the group. Expert pilots are suggested to have better decision making and diagnosis ability than less expert pilots. Experience is a factor in GA accidents as older pilots have higher rates, but in the Part 135 category older pilots had accident rates at the same rates as other age categories.

The articles on touchscreens highlight the issues with vibration, turbulence and interaction on the aviaton flight deck during all flight operations. The articles also examined ergonomic aspects and different locations of the touchscreens as well as different interfaces. They also highlighted the advantages to incorporating touchscreens on the aviation flight deck in weight savings, ease of use over other technology, and having all the pilot related tasks in one device as well as cost savings when upgrading software. Touchscreens have become common in all facets of life from smart phones, iPads, tablets, and automobile interfaces as well as automatic tellers, etc. Many computer systems are incorporating touchscreen technology into their computer monitors and laptops. One article suggested that in some circumstances, touchscreen interfaces were more acceptable to older adults than with younger adults. Touchscreen interfaces, buttons and tabs were suggested to be easier to use with the right size and spacing.

**Conclusion**

The articles from human interaction and automation, age related cognitive issues and advanced technology, expertise and experience and touchscreens altogether provide the material for the study. Taken together, human interaction and automation issues and age-related cognitive decline and advanced technology is an area that has been examined in the aviation environment for the past several decades. It has been generally accepted that older adults can have more issues with automation and technology due to age related decline. It has also been generally accepted that older adults have an aversion to new technology and automation. This does have an element of truth, but there are reasons for this that the articles examine and suggest.

The research that has been conducted on human interaction and automation provided evidence that there was a need for more transparency, appropriate levels of automation, information and interfaces be designed into the systems. The information that is presented needs to be clear, unambiguous and appropriate to the situation and without overwhelming detail. Interfaces for automation and older adults was suggested in articles on age related cognitive issues and advanced technology. Age related cognition decline is a normal fact of life, but occurs at different rates for every individual and is exacerbated by medical issues. Addressing medical issues, maintain a healthy lifestyle, nutrition, reducing stress and engaging in cognitive stimulation reduces the effects of cognitive decline in older adults. The medical issues and reasons for enacting the age 60 rule in commercial operations was found to have no basis when research was conducted. It was found that there were few issues of inflight incapacitation of pilots that led to accidents.

Training could possibly further ease issues of cognitive decline with aging and was found to have that effect in some areas. Further research in that areas and to examine how long those benefits are maintained is required. In the articles on experience and expertise it was found that it can mitigate cognitive issues with older pilots. Cognitive issues occur on an individualized level and it was not found to pertain to age groups. An individualized approach to older pilots is an area that warrants further examination as it pertains to flying age and cognitive decline from aging rather than set at one particular age. The increase in the number of pilots that will be required in the coming decades merits that all options be examined to have those positions filled. Excluding pilots because they have reached an arbitrary age and not based on their cognitive and physical health is one area that could be examined.

Touchscreens are being introduced on the aviation flight deck for weight and cost savings and providing all the tasks that are required of pilots to be in one device that can have multiple locations. The articles examined issues that touchscreens on the aviation flight deck faced, on vibration, turbulence, ergonomics and interaction, and found ways to address those issues. Touchscreens, like smart phones, tablets and iPads, are more intuitive and interactive then the avionics devices that they are replacing. This technology has become common in everyday use having been incorporated into ATM's, smart phones, automobile interfaces, computer monitors, etc. and all adults have become familiar with them. Touchscreen technology will improve pilot interactions on the flight deck in completing tasks as well as improve pilot performance. The present study will examine and possibly provide data that this is the case.

This study examined the effects of age, new technology, automation and touchscreens with pilots and their age. It examined the possible difficulties, ease of use and understanding on their working and interacting with touchscreens. The articles provide the background information and data for the two hypotheses that were tested to possibly find if the effects of age affect pilots learning, interacting, working, and performance with touchscreens.

# Chapter III
# Methodology

## Research Approach

The research approach in this study was a mixed methods questionnaire consisting of qualitative and quantitative questions. This provided the data to examine the interaction and working with, and the understanding of touchscreen use on the aviation flight deck and pilot age. A mixed methods approach gave the study a holistic examination of pilot age and touchscreen interactions including the observations and insights of the participants. Questions were designed that require specific selections for interaction with touchscreens and the data for quantitative statistical analysis. These were followed by open ended questions that required the participants' observations and insights that provided the study the data for qualitative analysis. Quantitative examination provided a causal look at pilots age and touchscreens and may not provide a complete picture. Qualitative examination provides a more detailed look at pilot age versus touchscreen use and may provide underlying reasons for differences. The mixed methods approach allowed the participants to elicit their insights in their own words and detail on working with touchscreens, interactions, ease of use and areas that were difficult. The qualitative questions were tailored to provide the participants insights from the quantitative questions. This provided data and information of the observations and insights of the participants that were examined by the age groups separated into categories.

Using a mixed method of qualitative and quantitative data provides triangulation and depth, giving more validation to the results. It was used in this study and gave the participants the ability to give their insights and views on the training process and touchscreens that may provide areas of improvements or future development. Three follow up open ended questions were used to clarify or elicit additional information as needed, from the participants. A mixed method approach can give an estimate of the training program from the participants' views on it and what is currently being taught (Yoshikawa, Weisner, Kalil, & Way, 2008). Quantitative data from the questionnaire provided the data of the pilots and their age with how they interact, gain knowledge and understand touchscreens. The qualitative data from the questionnaire provided context to how this is affected by age. Participants answering the open-ended questions provided deeper data and information on difficulties, ease of use and understanding on their working and interacting with touchscreens.

To test the two hypotheses the pilots were grouped into three age categories: 18 years old up to, but not including 40 years old; 40 years old up to, but not including 60 years old; and 60 years old and older. The participants were asked to provide background information with the demographic questionnaire of age, experience levels, ratings and licenses, type of touchscreen experience, gender and nationality. Touchscreens have been incorporated in GA, military and commercial aircraft and this study included those segments of civilian and military pilots. The minimum flight time will be 500 hours in aircraft with working experience with touchscreens. The follow up three open ended questions provided the participants the opportunity to clarify any ambiguity they may have felt answering the multiple choice and Likert questions. It also gave them the opportunity to provide additional information if appropriate and provide depth to the present study. The independent variable was the pilots' age separated into the three categories. This provided three levels of pilots' age for the examination of their interaction with touchscreens. Additionally, the demographic background material that the participants provided will gave data for an examination of how experience corelates to pilot age and interaction with touchscreens. The dependent variable was the knowledge and competence of the pilots working and interacting with the touchscreens. This was examined with the amount of time to gain knowledge, understanding and comfort with the touchscreens.

**Design and Procedures**

An application was submitted to the IRB prior to any material, questionnaire, consent forms, etc. being released or published to conduct the present study as required for conducting research with human subjects. This is a requirement for any study with human participants and in accordance with Embry-Riddle and IRB policies. The application and the present study were accepted and approved prior to moving forward. The questionnaire was published online, at esurveycreator.com, with the other forms that were required for participation in the present study. A consent form was provided and completed prior to the participant being able to access the questionnaire. Instructions were provided for the questionnaire and an additional demographic background form for the participants to complete. Once these forms were completed, the participants were able to access the questionnaire and complete it. The quantitative questions were composed of five multiple choice questions and 10 questions that were answered with a five point and seven-point Likert scale. Each multiple-choice question was followed by two questions based on the Likert scale. The multiple-choice questions were designed to address the levels and comfort with new technology and automation. The follow up Likert questions were designed to further refine the comfort level with automation and technology and touchscreens. This was accomplished by using a unipolar question followed by a bipolar question. Unipolar questions focused the participants on the presence or absence of a single item regarding touchscreen interaction. This focused the participants on a particular attribute of their interactions with touchscreens. The bipolar questions focused the participants on providing a balance on opposites regarding touchscreen interactions. This required the participants to balance between the extremes on their interactions with the touchscreens. There were five open ended questions that gathered qualitative data and information. One qualitative question followed each of the multiple choice and two Likert questions and this provided the participants a question to answer with their inputs, issues and abilities to work with touchscreens. It also provided the participants in this study for their feelings and opinions to be stated as well as provide insights on satisfaction and improvements to the technology and training program. After completion of the questionnaire, the participants were given a form with three open ended questions to provide more information, clarification or insights that they may have that were not addressed from the questionnaire, or that have occurred to them as they completed the questionnaire. This supplied more detailed qualitative data and information from the participants in addition to the questionnaire. Participants were given the opportunity to supply insights and information that may not have been elicited from the questionnaire and provide more detail with these questions. The next step for the participants was to fill out a debriefing form that defined this study and the examination of pilot age and touchscreen interactions. The form included the researcher contact information if the participants had any concerns, comments or questions.

**Apparatus and Materials**

The present study materials were confined to the questionnaire, and related forms, consent, instructions, etc. No other material was provided except these forms and three open ended follow up questions for clarification and additional data and insight. There was no apparatus, program or device that was used or any apparatus, program or device similar to a touchscreen for the participants to interact with.

**Sample**

The sample size was open for up to 50 participants, with a minimum of 25 participants, from the civilian and military pilot pool that works with touchscreens that elect to participate in the study. The participants had valid private, commercial, airline transport (ATP) licenses or military equivalents and attested to this on the demographic background form. The total sample size was 55 pilots with one participant selecting to decline, six selecting to participant but not answering any questions and 48 answering varying levels of questions. This level of participation was enough to be significant and provided the data for statistical analysis to have validity. The intent was to make the questionnaire available for the widest number of participants across the worldwide aviation community that work with touchscreens. It was also the intent to for the participants to be from the full spectrum of the aviation community, GA, commercial operators, etc. that work with touchscreens on the flight deck.

**Sources of the Data**

The aviation community of pilots, GA, commercial, corporate, etc. that work and interact with touchscreens was the source of the data for the present study. Data was provided from the questionnaire designed for the present study with qualitative and quantitative questions for the pilots that work and interact with touchscreens. The questionnaire was published online at esurveycreator.com and available for pilots to access and answer, once they consent to participation in this study. It was open and available for approximately five weeks for pilots to access and complete during that time and submit their answers. At the end of the open period the questionnaire was closed and the data collected for examination and statistical analysis had 55 participants with one declining, 54 answering part of the survey, and 38 answering all the questions in the survey. This number of participants was well beyond the minimum that was selected for the collection of data from pilot that work and interact with touchscreens.

**Validity**

In this mixed methods study, the use of a qualitative and quantitative questionnaire did provide triangulation from the data and provided validity to this study. The design of the present study gave credible and accurate data that potentially addresses pilot age and touchscreen interaction and gives the study validity. Validity and design of this study will provide the basis for others to duplicate the results in their examination of touchscreens and pilot age. This potential replication in other studies by other researchers will provide this study with external validity. The sample of pilots worldwide that interact with touchscreens will be representative of that category and provide additional external validity for this study. The triangulation of a mixed methods approach used in this study provided internal validity. The examination of any inconsistencies and differences in the present study hypotheses and the qualitative data that participants provide will be examined and accounted for. Revisions of the hypotheses or explanation will be given to account for the differences and provide validity. Additional validity was provided by the examination of the thesis committee and a peer review.

Examination of the qualitative data and the quantitative data was accomplished separately, in different ways for the final results, non-statistical for qualitative data and statistical for the quantitative data. The qualitative data was examined from the open-ended questions and interviews to identify recurring themes, ideas and information. This gave depth to the quantitative data final results. The quantitative data was analyzed by the three pilot age group categories with an analysis of variance (ANOVA) to determine statistical significance between the groups. If there is no statistical significance then the results, for the present study, would show that there is no difference in pilot age and working with touchscreens. If there is a difference then, for the present study, it would show that there is a difference in pilot age and working with touchscreens. The use of ANOVA is assuming normal distribution within each group. For this study if the results show that there is a difference in pilot age and working with touchscreens, further statistical testing using Tukey HSD Post Hoc to compare the three categories to determine which one or which two are significantly different from the others.

**Treatment of the Data**

The present study was conducted in accordance with the guidelines outlined by Embry-Riddle Aeronautical University and with the IRB. The data was treated with confidentiality and the participants were able to opt out at any time during study. The participant's individual information was protected in all data that results in the present study in an encrypted file on an encrypted laptop. No personal information other than age, experience levels, ratings and licenses, type of touchscreen experience, gender and nationality will be collected and all responses will be anonymous. Participants were assigned numbers for their questionnaire and their names removed with that data only available to the author. The IP addresses or any other information that can be used for identifying the participants was not saved from or by the online survey. The data was stored on an encrypted computer file on one laptop only accessible by the author and was backed up on a USB drive that was encrypted and stored under lock and key box available only to the author to access the data. This will protect the anonymity of participant responses and all information collected as part of this study and will not be used or distributed for future research studies. All information and data collected from participants that elect to opt out of the present study were erased, deleted, removed or destroyed.

# Chapter IV
# Results

## Demographic Data Review

After IRB approval on January 27, 2020, the questionnaire and demographics survey were published online on January 30, 2020 at esurveycreator.com and open until March 07, 2020. The total number of participants was 55 with one participant declining participation in the survey and six others selecting yes to participate, but not answering any of the demographic questions or the questionnaire (Appendix G, Figure 9). The demographics survey had 48 participants answering all 15 questions and there were two female participants and 46 male participants (Appendix G, Figure 10). For the age groupings there were 12 participants for the group of 18 years old up to, but not including 40 years old; 26 for the group of 40 years old up to, but not including 60 years old; and the number of participants 60 years old and older was 10 (Figure 2).

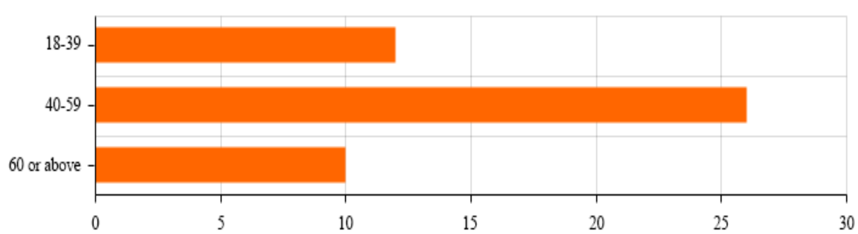


Figure 2. Age categories of the participants.

There was a high concentration in the number of participants that hold advanced licenses and ratings, particularly ATP and type ratings. Out of 48 participants answering the question on highest license attained 42 hold ATP license, five hold a commercial license, and one holds a private pilot's license (Appendix G, Figure 11). On the question of holding an instrument rating, 47 participants hold it and one participant does not have an instrument rating (Appendix G,

Figure 12). There was a high concentration of type ratings held and only three out of the 48 participants do not have a type rating. 13 participants hold one type rating, 17 participants hold two to four type ratings and 15 hold five or more type ratings (Figure 3).

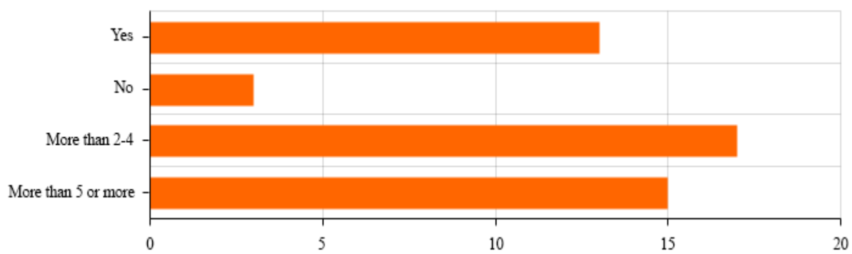


Figure 3. Type ratings.

The majority of the 48 participants are currently flying with only four of them not flying and 36 are flying as their primary occupation while 12 are not (Appendix G, Figure 13; Figure 14). There was a heavy concentration of the participants flying Gulfstreams, with 32 out of the 48 flying them. One participant answered Bombardier for aircraft flying, three answered Cessna and 12 pilots answering others, indicating that they fly another type of aircraft (Figure 4). Total flight time was concentrated on the higher end from the 48 participants that answered this question. Four participants have under 1000 hours of total time and 15 have total time between 1001 and 5000 hours. The majority of participants, 19, have between 5001 and 10000 hours and 10 participants have over 10000 hours of total flight time (Figure 5). There was a mix of type of flying, but mostly concentrated in the GA and corporate areas. From the 48 participants for this question eight answered flying Part 121 operations, three answered Part 135 operations and three answered military operations. 15 participants answered flying GA and 19 answered flying corporate operations (Figure 6).

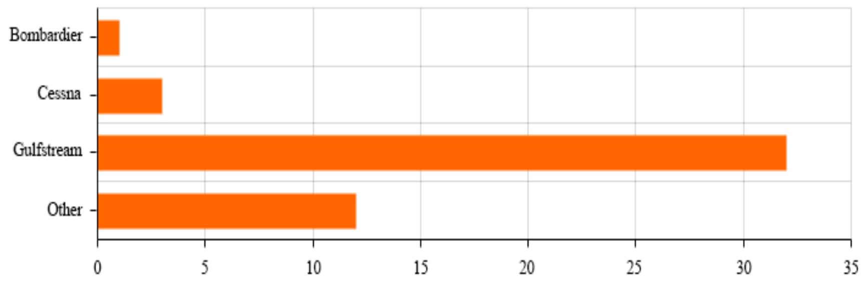


Figure 4. Aircraft flying.

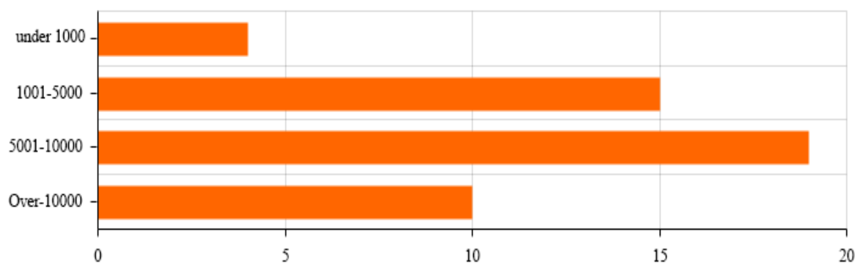


Figure 5. Total flight time.

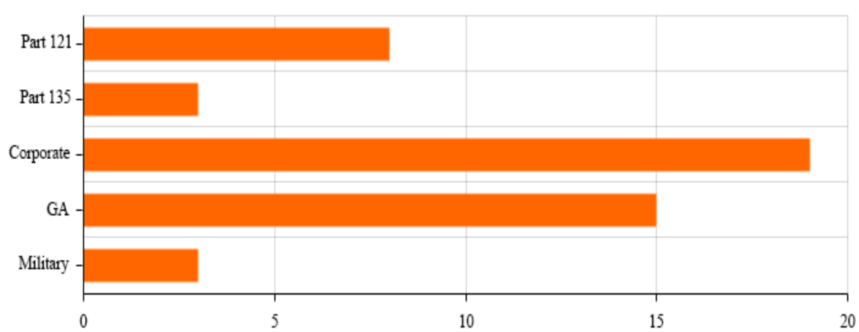


Figure 6. Type of flying.

All 48 participants have and use a smartphone and 44 of those have a personal tablet/iPad that they use, with four answering that they did not have one (Appendix G, Figure 15; Appendix G, Figure 16). The number of participants using a tablet/iPad for work use was similar with 45 answering yes and only three answering they did not use one (Appendix G, Figure 17). The majority of participants from the 48 that answered about touchscreens that they interact with use Honeywell for flying. 33 of the participants selected Honeywell, four selected Rockwell Collins and 11 selected other for type of touchscreen (Figure 7). A little over half of the 48 participants reported using touchscreens for longer than three years. Seven participants reported using touchscreens for less than one year, 14 reported using touchscreens for one to three years, and 27 reported using them longer than three years (Figure 8).

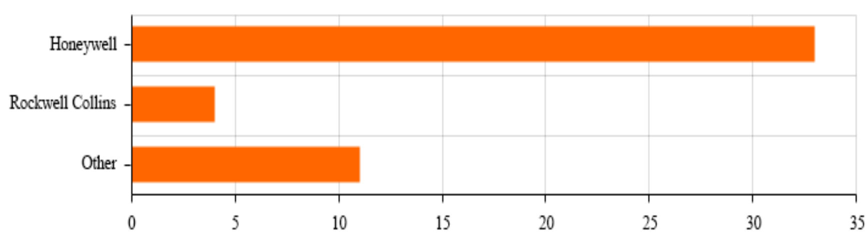


Figure 7. Type of touchscreen.

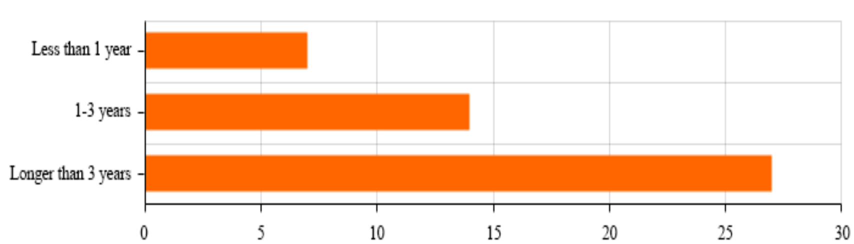


Figure 8. Length of time using touchscreens.

**Quantitative Data Review**

The level of participation for the quantitative and qualitative questionnaire had lowering levels of responses in the progression of those starting to answer to those that finished the entire survey. There were two sections; one section composed of a mix of quantitative questions, 20 total, five multiple choice, 10 that were answered with a five point and seven-point Likert scale and five that were opened ended. Each multiple-choice was followed by two based on the Likert scale and then followed by one open-ended question. The other section had three open ended questions to provide more information, clarification or insights that they may have that were not addressed from the questionnaire, or that have occurred to them as they completed that section. There were 47 participants that started the questionnaire portion, 40 that answered all the first section of 20 mixed multiple choice, Likert and open-ended and 38 that finished the entire survey answering the final three open ended follow ups. The first open ended question was where the first participant stopped answering and over the rest of the survey eight more stopped their participation in the survey. An interesting observation by the researcher is that the dropout rate occurred in only two of the age groups with all the participants in the 60 years old and older category, 10 pilots, starting and finishing the entire survey. The first participant answering all the demographic portion, but not any of the questionnaire was in the age group 18 years old up to, but not including 40 years of age. By the end of the first section of the questionnaire, the number of participants in the age group 18 years old up to, but not including 40 years of age had only six participants finishing after 12 had started. This is a dropout rate of 50%, half of those that started participation in the survey from the beginning ended up finishing this section. Only four answered the last qualitative and the three-open ended follow up questions. In the age category of 40 years old up to, but not including 60 years of age 26 had started the demographics and questionnaire and 24 finished the first section of the questionnaire representing just a little more than 9% dropout rate.

The first section of 20 of quantitative and qualitative questions had 40 participants answering all of them. The 15 quantitative questions yielded different results from no statistical significance for the majority, eight, to borderline statistical significance for three of them, and four that showed statistical significance. The qualitative questions yielded different results with the answers ranging from one word to one or two sentences to several sentences and in some cases multiple paragraphs. The second section of the three qualitative follow up questions that gave the participants the opportunity to provide more data, information, clarification and/or insights that were not addressed from the questionnaire or that they had not mentioned in a previous response had 36 respondents to all those. These responses also had varying levels of information from a simple one-word response to a sentence or two, to several sentences. Some of these provided detailed in-depth qualitative data and information from those participants expanding on their answers in the qualitative questions. Participants were given the opportunity to supply insights and information that may not have been elicited from the questionnaire and provide more detail with these questions.

The quantitative questions were scored one to four on the multiple choice, one to five, and one to seven on the two Likert type questions (Hartley, 2013). A number one was assigned to the answers that indicated that the participant had difficulties with interacting, working, and understanding touchscreens, new technology, smartphones, tablets, and iPads. A number four, five and seven were assigned to the answers that the participants had easy or little difficulties interacting, working, and understanding touchscreens, new technology, smartphones, tablets, and iPads. For the seven-point Likert questions, the number four was assigned for the mid-point or balance between the extremes. These answer selections for the mid-point range were neutral, met expectations, and good. The extremes for these questions for negative were very dissatisfied and far below, and for positive were very satisfied, and far above. Answers to the questions were arranged from both negative to positive and positive to negative.

Research has shown that answers to Likert type questions may vary and differ depending on the format and similar questions starting with positive answers were ranked higher than questions starting with negative answers (Hartley, 2013; Hartley & Betts, 2010). By varying the questions from negative to positive and positive to negative the researcher was providing the participants the opportunity to fully analyze their answers from a negative point of view and a positive point of view. This opportunity enabled the participants to affirm their answers with interacting, working, and understanding touchscreens, new technology, smartphones, tablets, and iPads. Research has shown that five-point Likert questions may not provide the ability to capture the necessary data that is being sought and that a seven-point Likert question is more likely to give the participants the ability to provide a more subjective answer (Finstad, 2010). By using a mixed methodology study with quantitative multiple choice, five- point and seven-point Likert questions and qualitative open-ended questions the researcher sought a holistic balanced approach that would provide rich detailed data from the participants.

The qualitative questions for this mixed methodology study provided the participants the opportunity to elaborate on their experiences with interacting, working, and understanding touchscreens, new technology, smartphones, tablets, and iPads. This was to provide a source of rich, detailed data that cannot be found through quantitative statistical analysis only as well as possibly provide information on methods of learning and understanding of touchscreens (Chigbu, 2019). These qualitative open-ended questions provide depth, validation, and are part of a holistic examination of the subject the effects of age on touchscreens, new technology and pilot performance. These questions were examined through the use of a qualitative case study approach, among the five, narrative research, phenomenology, grounded theory, ethnography, and case study (Creswell & Poth, 2018). The authors Creswell and Poth (2018) have explored and provide in-depth guidance on the differences in each type of study and how to apply them in qualitative research. Historical research has been included in other publications as an additional area of qualitative research (Chigbu, 2019). These questions are shown in table 10 and in Appendix I.

The quantitative questions were compared between the three age categories by statistical analysis using ANOVA calculations. Research has been conducted on whether parametric tests or nonparametric tests are the ideal way to examine Likert scale data and with sufficient sample size of five to 10 participants per group parametric tests can be used (Sullivan & Artino, 2013). All the age groups exceeded this number, although the age group 18 years old up to, but not including 40 years of age started out with 12 answering questions and this fell to six by the end of the survey. The ANOVA was run with a 95% confidence level providing that 95% of the observations will be within two standard deviations of the mean. For the questions where the hypotheses of the effects of age will have no effect on pilot's acquiring, learning, and gaining knowledge of touchscreen technology and other automation technology and the effects of age will have no effect on pilot's interaction and working with touchscreen technology and other automation technology were rejected a Tukey HSD Post Hoc test was run to check and examine those results. This was also run at the 95% confidence level and all the statistical analysis was conducted using StatCrunch, an online web based statistical software package developed by Pearson Educational, Inc. The quantitative question results had the majority of the questions, 11, showing no statistical significance, but two of them dealing with touchscreens would be at 0.05 if rounding to two decimal places. Four of the quantitative questions showed a statistical significance with p less than 0.05, 95% confidence level showing that there were effects of age having an effect on pilot's acquiring, learning, interacting, and working with touchscreen technology and other automation technology. A list of these questions is shown in table 1 and are included in Appendix H.

Table 1
List of quantitative questions and p value

| | | |
|---|---|---|
| 1. | I am one of the first to buy new products, especially technology | 0.6339 |
| 2. | I am competent with smart phones, tablets and iPads | 0.4534 |
| 3. | I am competent with the touchscreens used on my aircraft | 0.0707 |
| 5. | I set up, configure, add applications and programs easily on my smartphone, tablet, iPad and computer | 0.4719 |
| 6. | The touchscreen is intuitive and making selections with tabs and buttons is easy | 0.0525 |
| 7. | Please rank your ability in interacting, working and finding tasks with touchscreens | 0.0041 |
| 9. | I have a difficult time using applications on my smart phone, tablet or iPad | 0.0036 |
| 10. | I have a difficult time working with the touchscreens on my aircraft | 0.4177 |
| 11. | Please rank your abilities working with new technology, smartphones, tablets and iPads | 0.0199 |
| 13. | I have a hard time learning new things, especially technology, and try to avoid it | 0.2003 |
| 14. | Interacting and making selections with the touchscreens was difficult | 0.0523 |
| 15. | Compared to learning other new technology the total amount of time it took me learning to use and interact with touchscreens left me | 0.4291 |
| 17. | I have an easy time learning new things, especially technology, and embrace it | 0.0268 |
| 18. | I can easily find and navigate between the performance, flight planning, communications and the systems on the overhead panel touchscreens | 0.4186 |
| 19. | Please rank the difficulty learning, interacting and using touchscreens compared to other avionics packages that you have used | 0.4655 |

The following questions had no statistically significant differences between the age categories; number 1, number 2, number 5, number 10, number 13, number 14, number 15, number 18 and number 19 (Table 1). Questions 6 and number 14, were approaching statistically significant differences and were just outside the p less than 0.05, 95% confidence level. Question 3, “I am competent with the touchscreens used on my aircraft had a p-value of 0.0707” and suggests that they were issues that some of the participants had with touchscreens. The answers to this question from each of the age categories had variations at higher levels and this is shown in figure 9. The green line represents the mean, the red line represents the median. The gray fence represents an outlier of one in each of the categories with that outlier a lower score in the youngest two age category and the outlier in the oldest age category being higher than the other participants.

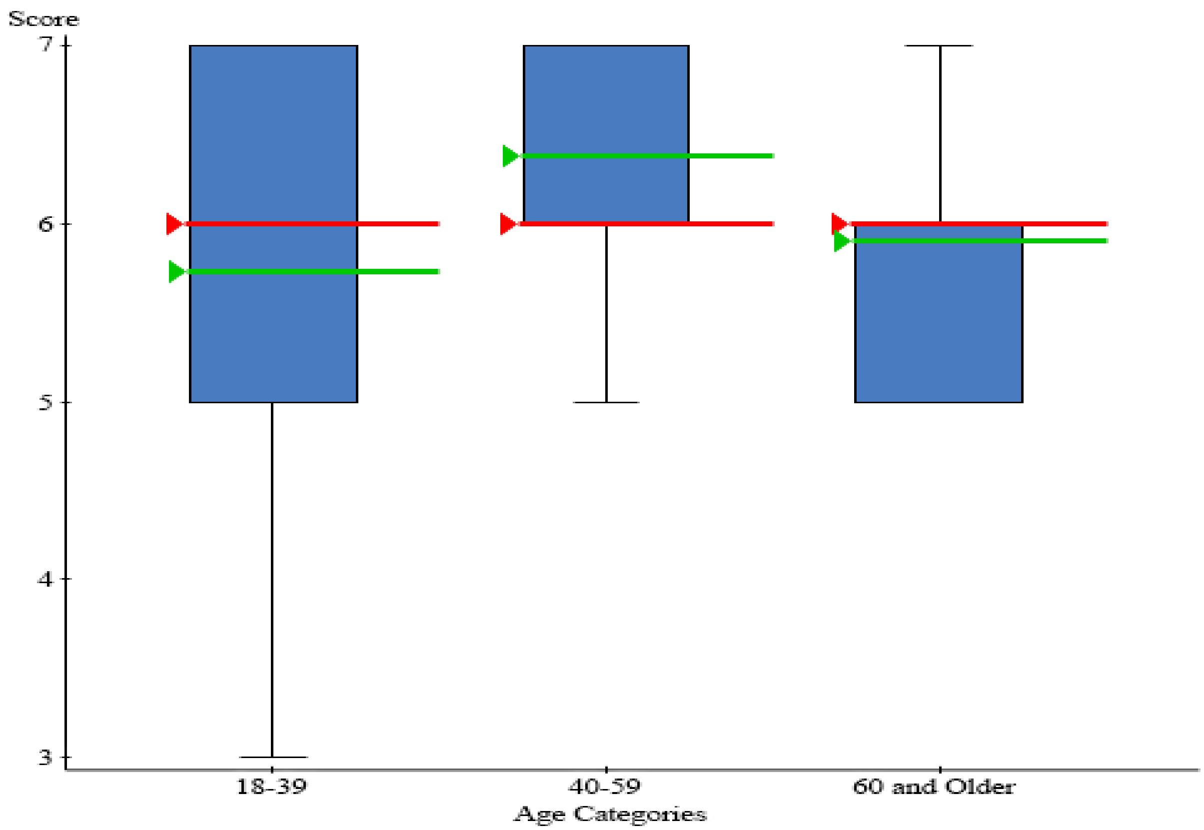


Figure 9. Competent with touchscreens on my aircraft.

ANOVA results for question 6, the touchscreen is intuitive and making selections with tabs and buttons is easy, the p-value was 0.0525 and the scores between the age categories showed similar results to question three as seen in figure 10. This is slightly above p .005 suggesting there were participants that did not find touchscreens that intuitive or easy making selections with the tabs and buttons. The results did not fall below 0.05, but rounding to two decimal places it is approaching the level of statistical significance. These questions deal with touchscreens and lend supporting data to the questions that are statistically significant.

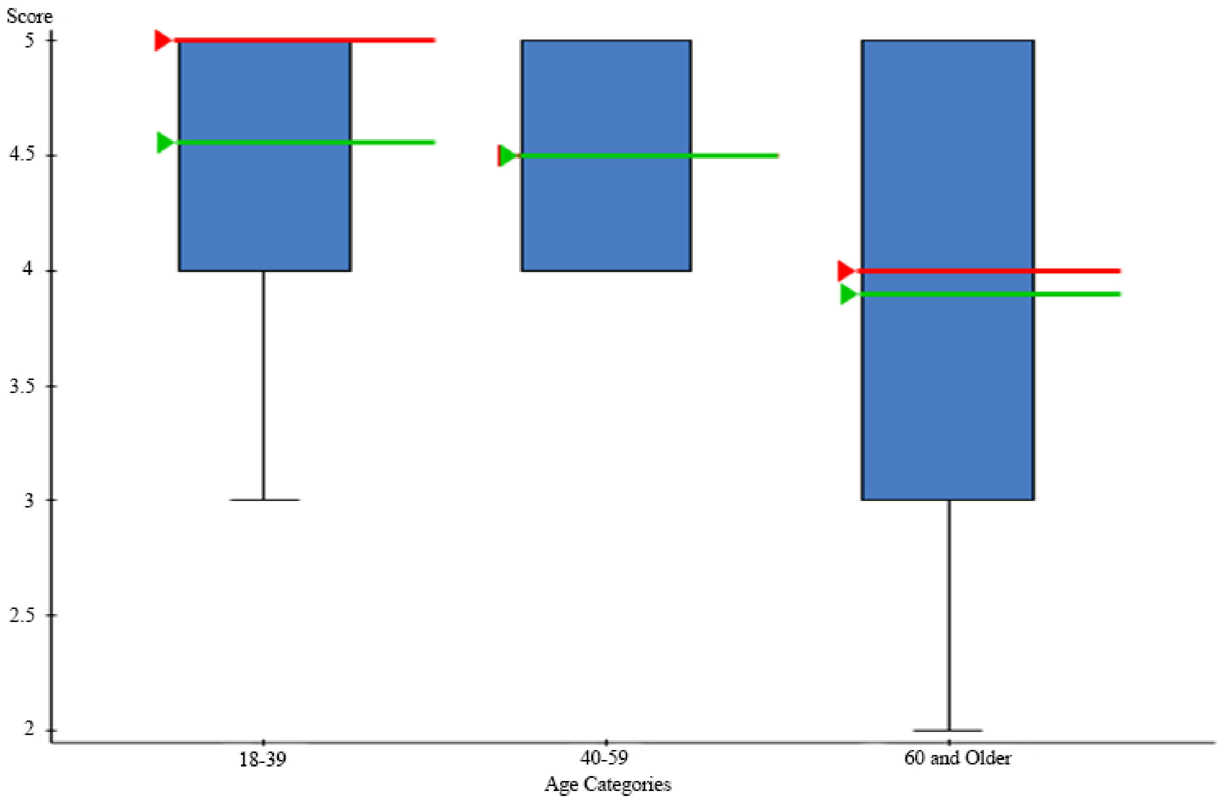


*Figure 10*. Touchscreen is intuitive and making selections with tabs and button easy.

Question 14, "interacting and makings selections with touchscreens was difficult" also had similar results to questions three and six and had a p-value of 0.0523, almost identical to question six p-value, with the results in figure 11. Both of these questions were based on a five-point scale and possibly this could have contributed to the results. Finstad (2010) suggested that a five-point scale may not provide enough refinement in the answer selections and that a seven-point scale would provide more refined results. It is an indication, as was question six that some participants had trouble interacting and making selections with touchscreens.

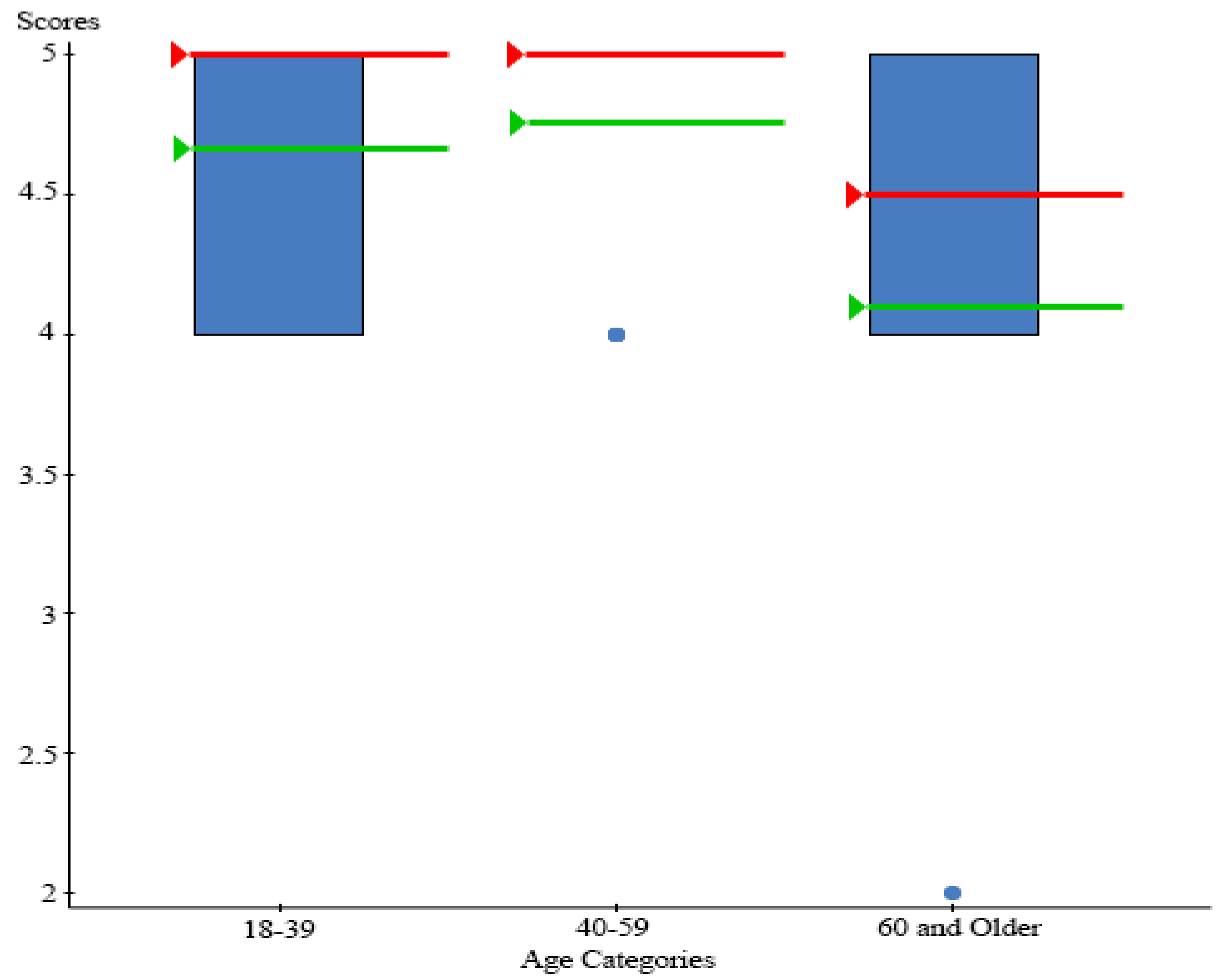


Figure 11. Interacting and making selections with touchscreens was difficult.

One of the questions that had a statistically significant difference was questions seven, please rank your ability in interacting, working and finding tasks with touchscreens that had a p-value of 0.0041 as seen in table 1. The result was fairly significant and this was the only one of statistically significant difference that was specifically about touchscreens. This result means that the alternate hypotheses has to be accepted that age does have an effect on interacting, working and finding tasks with touchscreens and other automation technology. Another indication of this is the high value of F of 6.2923.

Table 2
ANOVA of interacting, working, finding tasks, with touchscreens

| | df | SS | MS | F-Stat | p |
|---|---|---|---|---|---|
| Columns | 2 | 7.3573 | 3.6786 | 6.2923 | 0.0041 |
| Error | 42 | 24.553 | 0.5846 | | |
| Total | 44 | 31.911 | | | |

This was a somewhat greater variation than in questions three, six and 14 and the age 60 and older had the greatest spread in answering this compared to the other two age categories. One participant scored this question as a three ranking their ability interacting, working, and finding tasks with the touchscreen as slightly below. One of this group scored it as met expectations, two scored it as slightly above, five scored it as moderately above, and only one of the participants scoring it as seven, that their ability was far above. The seven-point scale for this question was far above, moderately above, slightly above, met expectations, slightly below, moderately below and far below and the score was started at seven for far above and ranged down to one for far below. This was in contrast to the age group 18 years old up to, but not including 40 years of age that had four participants scoring the question as far above, four scoring it as moderately above and only one scoring it slightly above and not one from this age group scoring the question lower. The age category of 40 years old up to, but not including 60 years had 11 participants scoring the question as far above, 14 scoring it as moderately above was seen in figure 12.

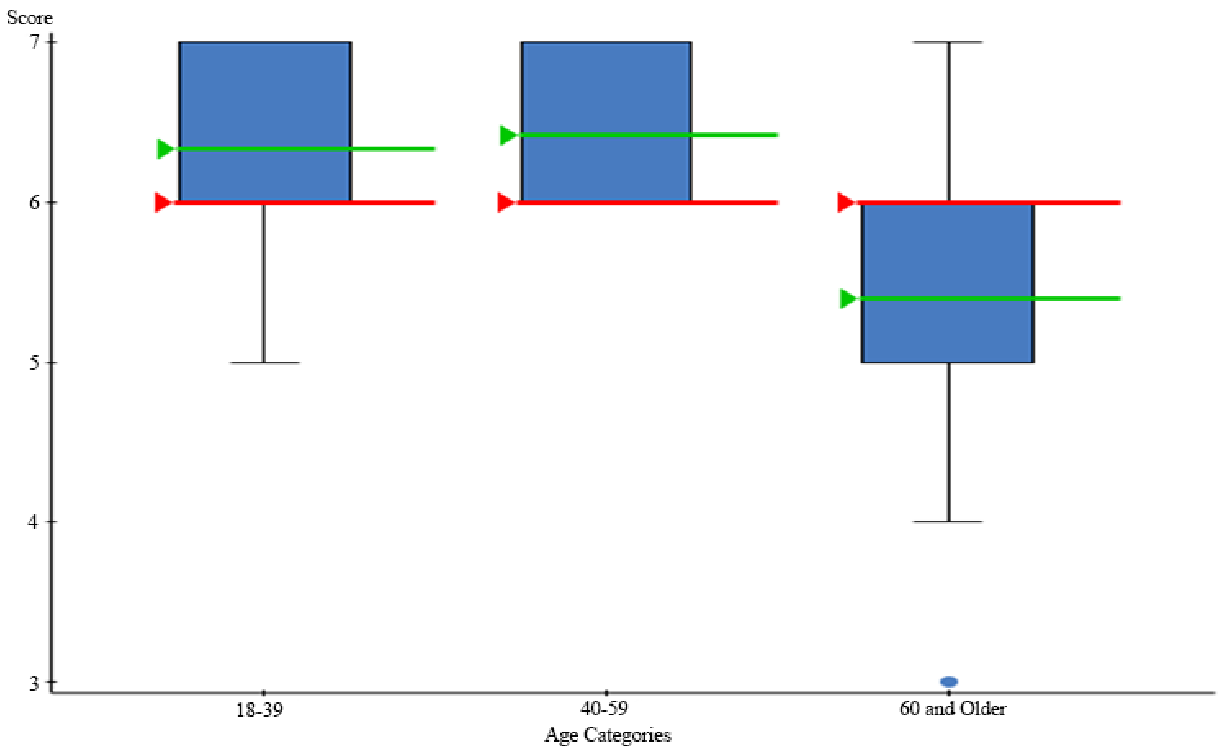


Figure 12. Rank ability interacting, working and finding tasks with touchscreens.

A Tukey HSD Post Hoc was calculated to determine which age category was significantly different from the other two. This was run at a 95% confidence level and the results are seen in table 2 showing that the age category of 60 and older is significantly different than the age categories of 18 years and older up to, but not including age 40 and age 40 years and older up to, but not including age 60.

Table 3
Tukey HSD Post Hoc Analysis

| | Difference | Lower | Upper | p-value |
|---|---|---|---|---|
| 40-59 | 0.0512 | -0.6671 | .7696 | 0.9836 |
| 60 and older | -0.9333 | -1.7868 | -0.0798 | 0.0293 |

40-59 Subtracted from

| | Difference | Lower | Upper | p-value |
|---|---|---|---|---|
| 60 and older | -0.9846 | -1.6758 | -0.29339 | 0.0035 |

Question nine was a multiple-choice question, I have a difficult time using applications on my smart phone, tablet, or iPad that was scored from negative to positive. The selection was most of the time, some of the time, seldom, and never. The p-value for this question was 0.0036 and the F value was 6.4588 showing that there were statistically significant differences between the age categories. There were some differences in all the age categories with the scores, but in the 18 years and older up to, but not including age 40, this was only between two participants selecting seldom and the other six selecting never. For the age 40 years and older up to, but not including age 60, there was a wider range with 19 selecting seldom, six selecting never and one selecting some of the time. The age 60 and older also had a similar range with seven selecting seldom, only one selecting never and two selecting some of the time and these results are seen in figure 13.

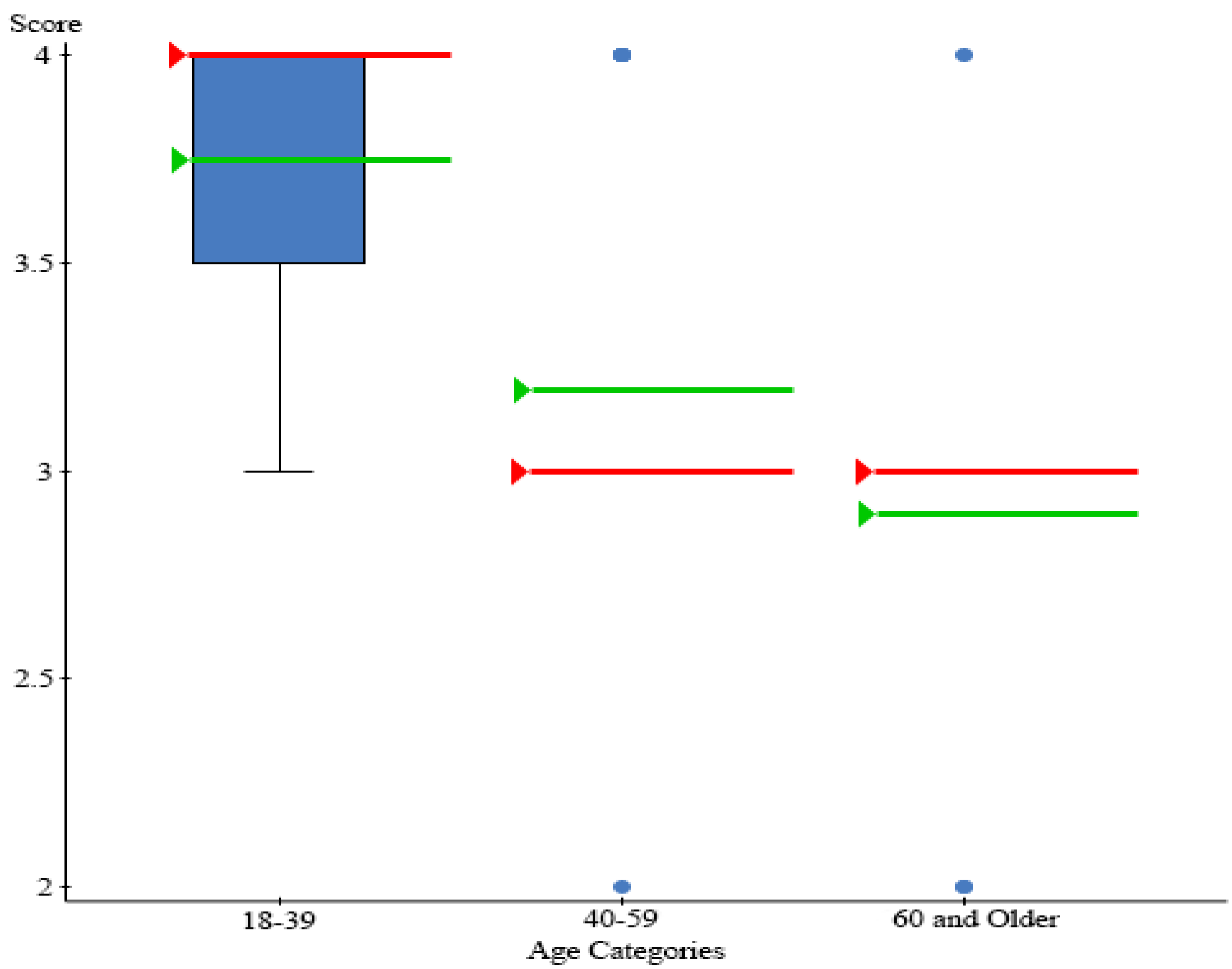


Figure 13. Difficult time using applications on my smartphone, tablet or iPad.

This is another question where the alternate hypotheses must be accepted and age does have an effect on interacting, working and finding tasks with touchscreens and other automation technology. The touchscreens in this question did not address the ones used on the aircraft flight deck, but indicate that some older adults may have issues with touchscreen technology. Table 3 shows the ANOVA results and Table 4 the Tukey HSD Post Hoc.

Table 4
ANOVA difficult time using applications on smartphone, tablet, iPad

| | df | SS | MS | F-Stat | p |
|---|---|---|---|---|---|
| Columns | 2 | 3.2888 | 1.6444 | 6.4588 | 0.0036 |
| Error | 41 | 10.438 | 0.2545 | | |
| Total | 43 | 13.727 | | | |

Table 5
Tukey HSD Post Hoc Analysis

| | Difference | Lower | Upper | p-value |
|---|---|---|---|---|
| 40-59 | -0.5576 | -1.0537 | -0.0616 | 0.0244 |
| 60 and older | -0.85 | -1.4319 | -0.2680 | 0.0028 |

40-59 Subtracted from

| | Difference | Lower | Upper | p-value |
|---|---|---|---|---|
| 60 and older | -0.2923 | -0.7488 | 0.1642 | 0.2757 |

The third question that showed statistically significant differences was number 11, "rank your abilities working with new technology, smartphones, tablets and iPads". This was a seven-point ranked ranging from positive to negative and the selections were far above, moderately above, slightly above, met expectations, slightly below, moderately below and far below. The question included the same devices as in number nine and included new technology and did not specifically mention touchscreens. The hypotheses must be rejected in this case and age does have an effect on interacting, working and finding tasks with touchscreens and other automation technology. This question had a p-value of 0.0199 as seen in Table 5. The high F value also indicates that there is a significant difference and that age does not have an effect is not true.

Table 6
ANOVA of abilities working with new technology, smartphones, tablets, iPad

| | df | SS | MS | F-Stat | p |
|---|---|---|---|---|---|
| Columns | 2 | 5.1734 | 2.5867 | 4.3192 | 0.0199 |
| Error | 41 | 24.553 | 0.5988 | | |
| Total | 43 | 29.727 | | | |

This difference was only seen from the calculations in the age category of 60 years and older and was not duplicated in the age category of 40 years of age and up, but not including age 60 years old as is seen in the question nine. In the age category of 40 years of age and up, but not including age 60 years old 13 participants selected far above, 11 selected moderately above and the remaining three selected slightly above, all in the positive range. In the age category of 60 years and older two selected far above, four selected moderately above, two selected slightly above and two selected met expectations, all either positive or neutral In the 18 years of age up to, but not including 40 years of age there were four participants selecting far above and the other four selecting moderately above. This is shown in figure 14 and the results of the Tukey HSD Post Hoc are seen in table 6.

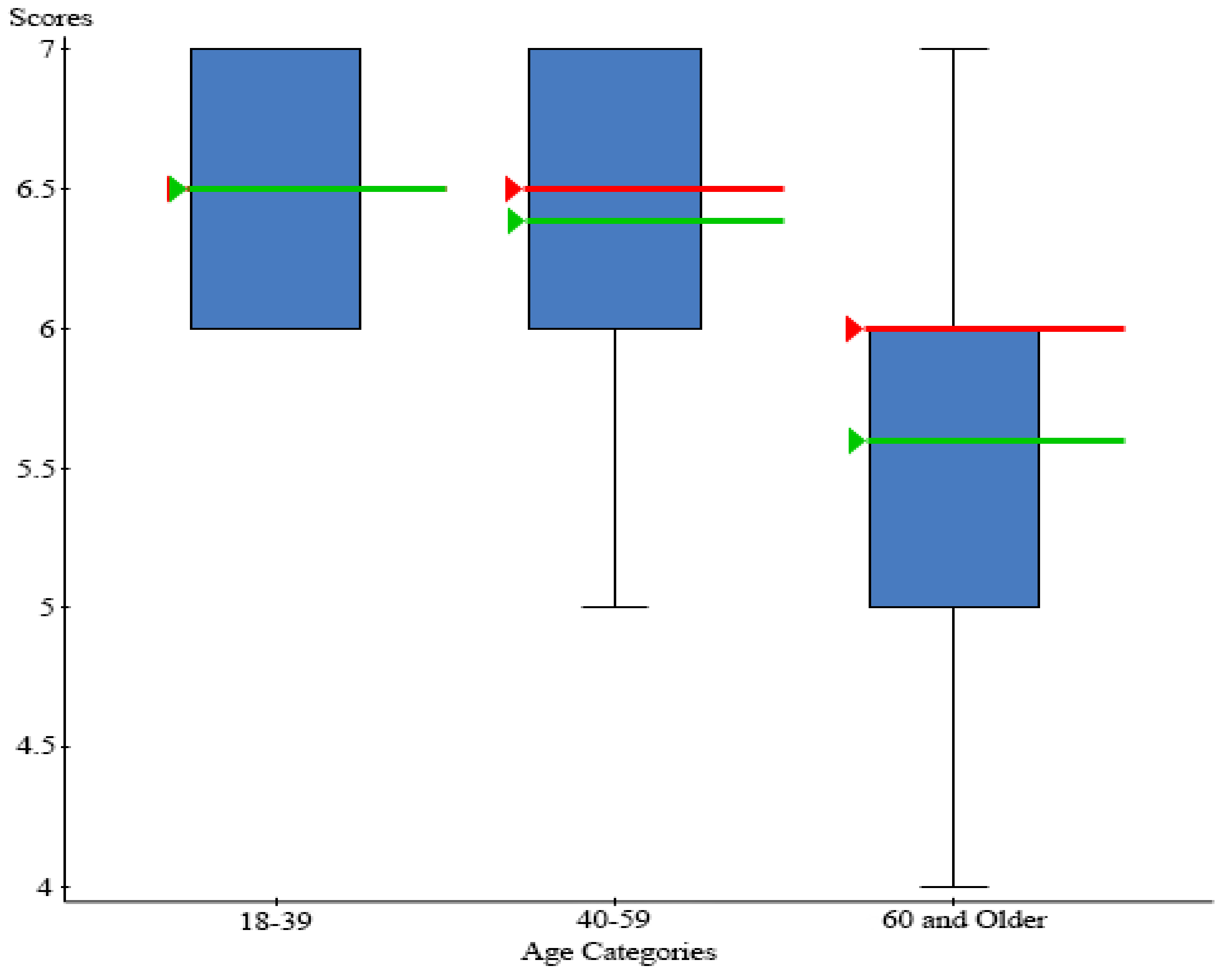


Figure 14. Rank abilities with new technology, smartphones, tablets, or iPad.

Table 7
Tukey HSD Post Hoc Analysis

| | Difference | Lower | Upper | p-value |
|---|---|---|---|---|
| 40-59 | -0.1153 | -0.8761 | 0.6454 | 0.9279 |
| 60 and older | -0.9 | -1.7926 | -0.0073 | 0.0478 |

40-59 Subtracted from

| | Difference | Lower | Upper | p-value |
|---|---|---|---|---|
| 60 and older | -0.7846 | -1.4848 | -0.0843 | 0.025 |

The last question that showed statistically significant difference was number 17, “I have an easy time learning new things, especially technology, and embrace it”. This was a multiple-choice question positive to negative with the four answers most of the time, some of the time, seldom, and never. The results showed that there was a category age does have an effect on interacting, working and finding tasks with touchscreens and other automation technology. All six of the participants in the 18 years of age up to, but not including 40 years of age selected most of the time. There was a little disparity in the age 40 years old up to, but not including 60, but much less than question nine, the other multiple-choice. In this case, 22 of the participants selected most of the time, only one selected some of the time and one selected seldom. For the age 60 years old and older five selected most of the time, four selected some of the time and one selected seldom (Figure 15). The p-value for this question was 0.0268 and the F value of 3.9972 as seen in table 7 and the post hoc calculations are seen in table 8.

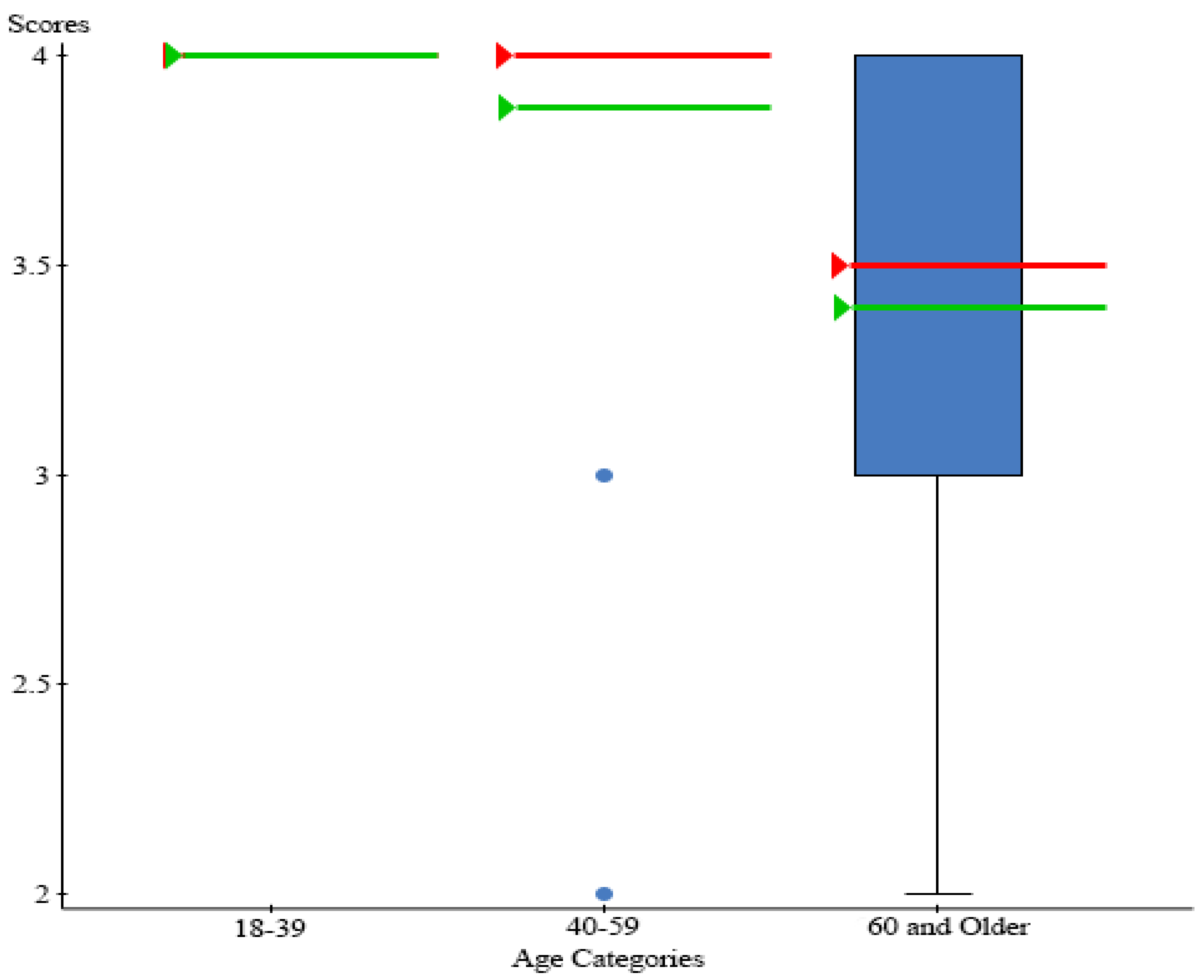


Figure 15. Easy time learning new things especially technology.

Table 8
ANOVA of easy time learning new things especially technology

| | *df* | *SS* | *MS* | *F-Stat* | *p* |
|---|---|---|---|---|---|
| Columns | 2 | 1.95 | 0.975 | 3.9972 | 0.0268 |
| Error | 37 | 9.025 | 0.2439 | | |
| Total | 39 | 10.975 | | | |

Table 9
Tukey HSD Post Hoc Analysis

| | Difference | Lower | Upper | p-value |
|---|---|---|---|---|
| 40-59 | -0.125 | -0.6753 | 0.4253 | 0.8448 |
| 60 and older | -0.6 | -1.2226 | -0.0226 | 0.0609 |

40-59 Subtracted from

| | Difference | Lower | Upper | p-value |
|---|---|---|---|---|
| 60 and older | -0.475 | -0.9288 | -0.0211 | 0.0386 |

**Qualitative Data Review**

The eight qualitative questions were tailored to the quantitative questions for the participants to provide additional data. This was also a way for more information, their observations, and their insights into new technology, smartphones, tablets, iPads, and specifically touchscreens. These are shown in table 11 and in Appendix I. The first five qualitative questions followed a multiple-choice question, a five-point scale question, and a seven-point scale question. The other three qualitative questions were separate and on an additional form, providing additional data. Information, observations, and any insights that the participants may not have provided or had the opportunity to provide in earlier answers. These three qualitative questions were provided in place of an interview follow up due to the time constraints of the thesis. The qualitative questions for this research were examined from a case study approach, limited to the demographic questions, questionnaire and the three open ended questions. A case study is normally stand alone, but multiple cases can be used to compare a subject, in this study examining the effects of age, new technology, and touchscreens (Creswell & Poth, 2018). The depth of the qualitative portion is not as in-depth as standard case studies and is without interviews, observations, and audiovisual, but the issue of age, new technology, and touchscreens is the theme of this present study (Creswell & Poth, 2018). The three follow up questions were given on an additional form to provide an area for additional data, observations or insights that may have been gathered from a follow up interview. These are shown in table 11 and in Appendix I.

Table 10
List of qualitative questions following the quantitative questions

| | |
|---|---|
| 4. | How easy or difficult is working with smartphones, tablets, iPads, touchscreens and new technology? |
| 8. | What worked well for you with learning, interacting and making touchscreen selections? |
| 12. | What were some of the questions or difficulties you had working with the touchscreens? |
| 16. | What do you like or dislike about working with technology, smartphones, tablets, iPads and touchscreens? |
| 20. | What was difficult with learning, interacting and making touchscreen selections? Why |

The first qualitative question was how easy or difficult is working with smartphones, tablets, iPads, touchscreens and new technology and had 46 participants provide answers. A good number of them ranged from easy, no issues, very easy, not difficult, etc. Some stated not at all, having to practice, becoming familiar with the device, understanding the logic or interface. Several differentiated between the devices, separating smartphones and iPads from touchscreens. Practice and training were mentioned as well as frequent use and maintaining proficiency with additional ground use. One participant discussed the English language, foreign pilots and English proficiency being an area of additional of possible difficulty with touchscreens for those pilots. Difficulty was characterized as having to find where the information was, practice and maintaining proficiency and one reference to missing push buttons.

The second question asked the participants to analyze what worked well for you with learning, interacting and making touchscreen selections and was answered by 45 participants. All of the answers to this question, except one, ranged from practice, training, how to videos, applications for simulating use and advice or asking questions of those familiar with touchscreens and one stated that it was their age. One participant also mentioned that the touchscreen initially was not intuitive, but with practice and repetition, it became intuitive. The one participant that did not actually answer the question stated that they were the pilot that wrote the requirements for that touchscreen and had worked with electrical engineers and human factors engineers.

To follow up the second question the third one asked what were some of the questions or difficulties you had working with the touchscreens and 44 participants provided answers. Several mentioned screen failures, durability, and turbulence issues interacting with them in flight. Eight answered none to this question. The other answers had to do with understanding tasks, how to find information or the path to the information needed as well as remembering how to find information or tasks that are rarely used. The other answers had to do with time for the selection of the task, resistive touch compared to capacitive touch, the pressure needed to make selections. The participant who designed the one touchscreen detailed the difference between personal devices and touchscreen, turbulence, resistive technology as well as incorporating a grip for stabilization. For this question, the two main points of difficulty with tasks in finding the information or following the path to the information or to complete the task. The other point was the amount of pressure for resistive touchscreens compared to other devices with capacitive touch and becoming comfortable making selections from one type to the other. The fourth qualitative question provided the participants with another opportunity to answer what do you like or dislike about working with technology, smartphones, tablets, iPads and touchscreens and

41 participants responded. The majority of the answers focused on touchscreens with only a few mentioning iPads or smartphones. One participant stated some concern, stated as “irrational”, that they would be left without access to airport approaches, arrivals and departures if the devices failed and they had no paper backups. All the answers ranged across many different subjects, some previously mentioned in the other questions, different touch needed between devices, find information, remembering the path to complete tasks, practice etc. These were very few of the response and the majority provided positive feedback. Most of the participants mentioned increased capability, software design, interface design, reduced workload, user friendliness, future changes with software updates, flexibility, especially being able to access tasks in one device. Several participants addressed that hardware would not have to be changed only software for updates, new abilities, new applications as well as incorporation of colors, shapes and graphical capabilities that the touchscreens allow. They also mentioned that this provided more information in an easier way to understand and comprehend.

The last qualitative question in this section dealt exclusively with touchscreens and that was what was difficult with learning, interacting and making touchscreen selections. There were 40 participants answering this question and almost half answered none, nothing, no difficulties, etc. The other participants answer all dealt with finding tasks, understanding architecture, remembering paths to information, familiarity, etc. The answers in this question were almost split on not having any difficulties at all to areas mentioned in previous questions on finding tasks and information as well as familiarity and understanding. Larger buttons were mentioned as well as physically making selections and the pressure needed. One touched on training by stating the slow pace of instructors. Also, mentioned several times was this was easier than other interfaces although one mentioned trying to find the page needed information was on since it was different from previous interfaces in other aircraft. Turbulence was mentioned by two separate participants as an issue.

Table 11
Quantitative follow up questions

| | |
|---|---|
| 1. | Are there any ways that interacting and learning touchscreens could be improved? |
| 2. | Would you make any changes to how the touchscreens work, selections, layers, interface? |
| 3. | Is there any additional information, data or thoughts that you have? |

The first question provided for additional information was are there any ways that interacting and learning touchscreens could be improved and this was answered by 38 of the participants. The answers were similar to previous questions from those that had no problems or difficulties and fell between no, nothing, nothing at this time etc. Several mentioned training and repetition to more interactive training applications to practice with. Some of these mentioned having specific paths to practice for finding specific information or tasks. The focus here was more training, practice, better training applications and understanding how the logic. One participant mentioned having proficiency matrixes so that training could be tailored to each individual. One mentioned adding touchscreen capability to the DU's as a step to input data directly to those rather than with an interface.

The second qualitative follow up question allowed the 38 participants to give their input on would you make any changes to how the touchscreens work, selections, layers, interface. 24 of the participants answered some form of no, none, not yet, etc. The participants that had input mentioned size of the icons, moving information form one page to another, pressure selection as well as more responsive touch and quicker processing speed, installing a push button keyboard. One participant suggested capacity screens for faster response, but with accidental touch or selection protection. The responses for change was relatively minor, other than the capacitive change, and dealt with location of tasks, pressure for selection and processing speed. The processing speed deals with the "delay" in resistive touch to ensure that the selection made is the one that is needed and not an accidental touch.

The final question provided the opportunity for the participants to give any additional information, data or thoughts that you have and 38 responded. Only five had input and the rest answered some form of no, not at this time, none and one N/A. Several mentioned the ability of touchscreens to easily modify the interface, selections, and compared to other avionics. One participant suggested greater interconnectivity of devices in the airplane and from other sources. And one participant stated that proficiency in these devices comes from practice and repetition. Increasing the interconnectivity of touchscreens was the only answer that suggested changing the way touchscreens are currently being used on the aircraft flight deck.

# Chapter V
# Discussion

## Discussion

The purpose of this study was to examine pilot age, touchscreens, new technology, and automation to determine if there are differences between three age group categories interacting, working, and understanding and if any differences may be cognitive, age related, or issues with technology and automation, or there may be no differences in age groups. These groups were 18 years old up to, but not including 40 years old; 40 years old up to, but not including 60 years old; and 60 years old and older. There were 15 quantitative questions and eight qualitative questions with the majority, 11, of the quantitative questions showing no statistically significant differences (Tables 1, 10, and 11).

Two of these questions, number 9 and number 11, dealt with smartphones, tablets and iPads, and 11 included new technology with the others. Question 9 was specifically having a difficult time using applications on the devices and 11 was ranking your abilities with those devices and new technology. On the question of having a difficult time using applications, there was more disparity in the scores ranging from two to four for the two age groups of 40 years old up to, but not including 60 years old, and 60 old and older. This was also seen, but at less disparity, in the 18 years old and up to, but not including 40 years old age group. The range in this group was three to four and this question was multiple choice with only four choices available, most of the time, some of the time, seldom, and never.

The other question on smartphones, tablets, and iPads included new technology for ranking your abilities working with them and was scored on a seven-point scale. This was positive to negative, far above, moderately above, slightly above, met expectations, slightly below, moderately below, and far below. All eight participants from the 18 years old and up to, but not including 40 years of age selected far above, four, and moderately above, four. In the age group 40 years of age up to, but not including 60 years of age, there was a little more range, but these were still significantly positive from far above, 13 or half of the 26, moderately above, 10 participants, and slightly above, which was the remaining three participants. A little more range was seen in the 60 years old and older, but still mostly positive selections and no negative selections. Out of the 10 participants two selected met expectations, two selected slightly above, two selected far above and four selected moderately above. These results seem to mirror previous research and literature regarding new technology and devices and older adults, but the lowest score was met expectations for two out of the 10 participants, while the rest were positive.

Examining the qualitative data from the open-ended questions there were two that can be applied to these two quantitative questions. Question number 4 asked how easy or difficult is working with smartphones, tablets, iPads, touchscreens and new technology and number 16 asked what do you like or dislike about working with technology, smartphones, tablets, iPads, and touchscreens. Most of the participants focused on touchscreens in these two questions, but there were a number that mentioned the other devices. There were areas that focused on specific aspects of working with the devices as well as the ease or difficulty. Points that are repeated in both questions, and also directly to touchscreens, is training, practice, and interface and ease of use when the participants addressed the difficulties or dislikes.

There were two points that can be seen from this data, one being the technology is easy, efficient, reduces workload, makes tasks easier and makes the participant more productive. Also, that the devices can be used to conduct multiple tasks, although one participant stated that this was a drawback with personal devices as it is easy to start out doing a task and end up doing other tasks, email, internet, etc. and not accomplishing the original task. This participant stated that aircraft devices are used for aircraft task and for this reason they are better. Many participants used either easy, very easy, or one of those with a qualifier, once you understand the technology, have the training, practice and degree of use.

In the age category of 18 years older and up to, but not including 40 years of age, there were only two of the 10 that stated additional items other than easy on question four. With question 16, the five of the six participants elaborated a little more, with the one contributing the most information was specifically about touchscreens. This participant stated understanding the logic of the technology being beneficial and correlated it to aircraft touchscreens. The other two age categories had the majority of participants who stated qualifiers, once you understand the technology, have the training, practice and degree of use, with easy or very easy. These two groups also provided the most data, information and insights, rather than simple one or two words to these two questions. Training, proficiency, and use on a regular basis were mentioned and expanded on.

Examining the data from these two questions and the information provided by the participants adds data to quantitative number 9 and number 11. The age category 18 years older and up to, but not including 40 years of age, stated very little issues with either of these two quantitative questions and the qualitative ones other than a several times mentioning logic and technology, interface ease of use, and needing a short time getting used to new software updates. It was in the other two age categories, the age group 40 years of age up to, but not including 60 years of age, and 60 years of age and older that issues with new technology, smartphones, tablets, and iPads, were seen in the calculated quantitative questions and were stated and addressed in the qualitative answers. These issue areas are training, practice, ease of use and interfaces, and learning. These two groups stated these issues at a greater rate than in the qualitative questions with the younger age category. This was not universal across every participant, but at a rate that it was statistically significant and there were several in both the older age categories that had no issues, embraced new technology, and were comfortable with it.

One of the other questions showing statistically significant differences was “I have an easy time learning new things, especially technology, and embrace it”. This was a multiple-choice question with answers ranging from most of the time, some of the time, seldom and never. All six participants that answered this question in the 18 years old and up to, but not including 40 years of age selected most of the time. It was in the other two age categories that a disparity in the range appeared, but no one selected never. In the age category 40 years old and up to, but not including 60 years old, the majority of the participants, 22 selected most of the time, one selected some of the time and one selected seldom. There were similar results in the 60 years of age and older, but more evened out, with five selecting most of the time, four selecting some of the time and one selecting seldom.

The two qualitative questions, 4 and 16, can be examined and the answers applied to this quantitative question as it was with number 9 and number 11. The issues that were mentioned previously, training, practice, ease of use and interfaces, and learning. The issues stated apply to this question as well, especially in the age category 60 years old and older. The two older age categories have mentioned, at a greater more consistent rate, that these areas are an issue when working with new technology, smartphones, tablets, and iPads. Previously in question 13, the participants were asked to respond to “I have a hard time working with new things, especially technology, and try to avoid it”. This was also a multiple-choice question and was negative to positive, most of the time, some of the time, seldom, and never. It was not rated as having a statistically significant difference, nor was it close, with a p-value of 0.2003. Question 17 was rated positive to negative opposite from number 13 and they possibly would have validated each other, but in this case they did not. Nor did they follow the research of Hartley (2013) and

Hartley and Betts (2013) that suggested that similar questions would be ranked higher when starting with a positive than a question starting from a negative premise. This research was specifically regarding five-point and seven-point scaled Likert test and not to a four-answer multiple choice, so that can be discounted from these two questions. Using a five-point or seven-point, as previously discussed gives more refinement to answering the question. Also, research has stated that a seven-point scale may provide more refinement than a five-point scale (Finstad, 2010). For this question, number 17, there was a significant difference, p-value 0.0268, that has data added from the qualitative data to affirm the difference.

The only question on touchscreens that showed statistically significant differences was question 7, “rank your ability in interacting, working and finding tasks with touchscreens”. This was a seven-point scale, positive to negative, far above, moderately above, slightly above, met expectations, slightly below, moderately below, and far below. For the 18 years older and up to, but not including 40 years of age, of the nine participants, four answered far above, four answered moderately above, and one answered slightly above. In the 40 years of age and up to, but not including 60 years of age, 11 participants answered far above, 14 answered moderately above and one answered slightly above. Again, there was disparity of range in the age category 60 years old and older with only one participant answering far above, five answering moderately above, two answering slightly above, one answering met expectations and one answering slightly below. The other questions on touchscreens that were five-point or seven-point dealt with interacting and making selections, intuitiveness, navigating between tasks, ranking difficulty compared to other avionics packages, and comparing learning to use and interact with other new technology.

The qualitative questions all specifically mentioned touchscreens, interacting with them, what worked well and what were the difficulties. Two of them also specifically mentioned touchscreens and how interacting and learning could be improved and what changes could be made to their selections, layers, and interfaces. The answers to these questions can be examined to add data to number 7 and provide information on the statistically significant difference. Much of the information provided from the previous three statistically significant ones is also stated regarding touchscreens and in the qualitative questions number 4, number 8, number 12, number 16, number 1, number 2, and number 3 (Tables 10 and 11). The areas frequently mentioned in the qualitative answers concerning touchscreens are training, practice, ease of use and interfaces, and learning. In addition, the other areas that are frequently mentioned was tab, icon, and button size, the amount of pressure, resistive and capacitive touch, and a consistent way to find tasks. One participant stated a positive about the touchscreens is the functionality and the ability to find tasks and information in different ways. It is this functionality and versatility that the participants stated having issues consistently finding information or completing tasks. Two mentioned interface and design, one cited one touchscreen manufacturer and the other one a different manufacturer. Another participant stated that there should be one design across all touchscreens. Several times participants mentioned having a standard input for interfaces or conventional keyboard for entering data and information. A conventional keyboard or input with through an application or buttons that when selected would perform several tasks was also stated by participants and these were from all three age categories. Processing speed was also mentioned several times, but this relates to the resistive touchscreens since a specific pressure must be used before the selection is made. This was the specific design for this type of touchscreen, Honeywell, and this was noted from the participant who was involved in the design of the touchscreen. This participant specifically mentioned that interacting with the touchscreen was specifically different than interacting with personal devices.

Issues about training had positive answers and information regarding the training applications that were used and provided. However, it was also mentioned that more interactive training and applications be provided. One participant recommended actual touchscreens for use in training and did mention that the cost would most likely be prohibitive. Instruction was also stated by participants, both formal, colleagues, and friends. Technology use was mentioned by one participant in the age 18 years old and up to, but not including 40 years old, when encountering a problem, they would google for information. Technology use in another way was mentioned by a participant in the age 60 years old and older, that they would use YouTube for online video learning. Understanding and using technology, including new technology and touchscreens was stated across all three age categories as being easy, not difficult and that they had no issues or problems. These answers, issues and lack of issues or difficulties across all three age categories lends data to the hypotheses that age does not have an effect on interacting, working and finding tasks with touchscreens and other automation technology.

Examining flying experience by highest license held, number of type ratings and total flight time had similar results when examining the questions with the issues that have been stated. Participants from all experience levels stated at least one type of issue or factor regarding touchscreen interfaces, location of information, completion of tasks, etc. Experience does not appear to be a factor although more of the issues stated were from participants that had higher levels of experience. When issues were stated, some were minor and many were addressed that with training, practice and experience the issue was no longer a concern. This was seen across the experience levels and was not seen in just lower experience or higher experience, whether by license, type ratings or total flight time. Additionally, when there was an issue on finding information or task, etc., the participant stating the issue would often provide information on how to address the issue. This was by steps, additional training or providing an example on what steps to take. This was seen across all experience categories.

**Summary**

The majority of the results provided data that age had no effect on pilot's acquiring, interacting, working, learning, and gaining knowledge of touchscreen technology and other automation technology. However, this data was not uniform and in a number of areas provided evidence that the effects of age does have an effect on pilot's acquiring, interacting, working, learning, and gaining knowledge of touchscreen technology and other automation technology. This data was provided by four statistically significant questions, number 17, "I have an easy time learning new things, especially technology, and embrace it", number 11, "please rank your abilities working with new technology, smartphones, tablets and iPads", number 9, "I have a difficult time using applications on my smart phone, tablet or iPad", and number 7, "please rank your ability in interacting, working and finding tasks with touchscreens" (Table 1). Two additional questions, number 6, "the touchscreen is intuitive and making selections with tabs and buttons is easy", and number 14, "interacting and making selections with the touchscreens was difficult", provide supporting data that the pilots had issues relating to interacting, working, and find tasks with the touchscreens. These two questions, if rounding down to two decimal places, is right at 0.05, but not below that threshold. However, this lends supporting data to the four that are of statistically significant difference. These six questions address touchscreens, new technology, smartphones, tablets, and iPads, and provide data that age has an effect on pilots acquiring, interacting, working, learning, and gaining knowledge of touchscreen technology and other automation technology.

The data provided by the participants in the qualitative sections lends additional support to the quantitative results. These questions specifically asked about touchscreens, interacting with them, what worked well and what were the difficulties. Two specifically mentioned touchscreens and how interacting and learning could be improved and what changes could be made to touchscreen selections, layers, and interfaces. These answers provided information and data on the statistically significant difference questions and gave areas where pilots had issues with the touchscreens. The areas that were mentioned are training, practice, ease of use and interfaces, and learning. Also, other areas mentioned were the layouts of touchscreens, tabs, icons, and button sizes, the amount of pressure, resistive and capacitive touch, and proscribed way to find tasks. This qualitative data and information provided depth to the statistically significant quantitative data and support for those results. It also provided data that might be used to alleviate and possibly eliminate the issues that the participants reported having with touchscreens and touchscreen technology.

The hypotheses that the present study sought to confirm was the effects of age will have no effect on pilots acquiring, interacting, working, learning, and gaining knowledge of touchscreen technology and other automation technology. The results provided data that this is not the case and that the alternate hypotheses must be accepted. This was by both quantitative and qualitative data that was provided by the participants. However, data and information about touchscreens and touchscreen technology, as well as training, training tools and applications provided by the participants show ways that this may be alleviated and possibly eliminated. Future research is needed to confirm these results as well as additional studies tailored with in person participation. Examining actual touchscreen use or an application that replicates touchscreens in an experimental study would provide more refined results than can be examined in a survey questionnaire alone. The results of the present study provide a foundation on which future research and studies may build upon to examine in-depth the effect of age and pilots acquiring, interacting, working, learning, and gaining knowledge of touchscreen technology and other automation technology.

# Chapter VI
# Conclusions and Recommendations

## Review of Research Approach and Participation

The present study was conducted to examine pilot age, touchscreens, new technology, and automation and the hypotheses that there are no effects of age on the pilots. This was accomplished by separating the participants in three age categories and examine differences in interacting, working, and understanding touchscreens, new technology, and touchscreen technology. The present study examined if any differences found may be cognitive, age related, or issues with technology and automation, or there may be no differences in age groups. This was accomplished by a mixed methodological approach with quantitative and qualitative data from a questionnaire that was published online and open to all pilots that work with touchscreens on the aviation flight deck. The survey started with a 15-question demographic background form for the data on flying experience by highest license held, number of type ratings, total flight time, touchscreen manufacturer, and to establish the age categories (Appendix D). This was followed by the questionnaire separated into one multiple choice question, followed by two Likert questions, one on a five-point scale and the other on a seven-point scale, followed by an open-ended question. Five-point scale are unipolar that focus on the presence or absence of a single item about the subject. The seven-point scale are bipolar focusing on providing a balance on opposites regarding the subject. The researcher used two types of Likert scales, five-point and seven-point, in an attempt to achieve a more holistic examination of pilot age, touchscreens, new technology, and automation. This combination was accomplished five times for a total of 20 and was followed by another separate form of three open ended questions. The multiple choice and Likert questions were scored to provide the quantitative data for the study and the open-ended questions provided the participants data, information and additional thoughts for the qualitative data.

The survey was published at esurveycreator.com and advertised online for pilot's participate anonymously. Initially 55 pilots selected the survey link and proceeded to the consent form, one declined to participate, six selecting to participate, but not answering any questions and the remaining 48 answering in varying levels. The number of participants that answered questions exceeded the minimum number of 25 and each category had a sufficient number of participants that it did not affect the results. The figures for the age categories answering the demographics form were 12 participants for the group of 18 years old up to, but not including 40 years old; 26 for the group of 40 years old up to, but not including 60 years old; and the number of participants 60 years old and older was 10. The final total of participation in answering all the questions, including the final three, was 38. The final number of participants per category was six participants for the group of 18 years old up to, but not including 40 years old; 22 for the group of 40 years old up to, but not including 60 years old; for the group 60 years old and older the number was 10.

**Questions Approaching Statistical Significance and Qualitative Support**

The data from the quantitative questions found no statistically significant differences in 11 of the 15 questions (Table 1). Question 6 and 14 were above 0.05 by statistical calculations, p of 0.0525 and p of 0.0523, but when rounding to two decimal places was right at 0.05 level. The researcher did not include them as statistically significant because they did not fall below the 0.05 level. However, they are approaching the statistically significant level and provide supporting data for the alternate hypotheses that age does have an effect on interacting, working and finding tasks with touchscreens and other automation technology. These two questions were five-point Likert scale and have less refinement than seven-point Likert scale choices (Finstad, 2010). Research has suggested that five-point scale provide participants the chance to interpolate between the answers and may not give their real accurate responses (Finstad, 2010). For this reason, the researcher did not include them as statistically significant, but as supporting evidence to accept the alternate hypotheses. Question 3 had a p value of 0.0707, above the 0.05 level, and with questions 6 and 14, all dealt with interacting, working, and making selections with touchscreens (Table 12). Question 3 was a seven-point Likert scale answer and number 6 and number 14 were five-point Likert scale answers. The data from these questions lends robustness to the questions that had statistically significant differences, that participants in the age group 60 years old and older have some issues when interacting, working, and making selections with touchscreens. These strengthen and provide supporting data with the statistically significant differences questions that age does have an effect on interacting, working and finding tasks with touchscreens and other automation technology. Examining the qualitative questions that dealt with smartphones, tablets, iPads, new technology, and touchscreens there are several areas stated that provide additional supporting data.

One area mentioned about touchscreens was finding the data or information, and learning, knowing, or remembering the path. This was mentioned on several questions when the participants were asked about what was difficult interacting, working, and making selections with touchscreens as well as ways to improve touchscreens, and what changes would the participants make. Several participants mentioned design, layout, appropriate shape and size of buttons, and intuitive interfaces when stating issues with finding data, information, or remembering the path to the data. This was mentioned by the majority of the participants in these different ways and was not limited to one age group. Through all three age groups this was mentioned as an issue or difficulty that they had when interacting, working, or making selections with touchscreens.

Countering that point the participants then stated that repetition, practice, learning or asking another pilot, and training was the answer to any issues or difficulties with interacting, working, and making selections with the touchscreens. Additionally, having intuitive interfaces and maintaining a level of work with touchscreens also countered issues with finding the data, information or path. Any of these issues that are mentioned were remedied and stated by the participants by repetition and working with the touchscreens themselves. The lack of statistically significant differences shows that, for the majority of the participants, touchscreens are intuitive. For those participants that stated touchscreen intuitiveness was an issue the more repetition and working, interacting, and making selections that they accomplished the more intuitive they became.

Another area that was stated frequently was the amount of pressure when making selections on touchscreens. This has to do with how the touchscreens are manufactured and whether the touch is capacitive, as are personal devices, smartphones, tablets, and iPads or aircraft touchscreens that are resistive and required a certain level of input before selection and activation of a task. Resistive touchscreens on the aviation flight deck are an answer to the issues of turbulence, vibration, and motion that previous research has found (Coutts et al., 2019; Dodd et al., 2014). Interestingly, two participants mentioned some difficulties with aircraft touchscreens, one specifically with turbulence and the other that it was easy to use under all normal conditions. Advances in touchscreen technology, interfaces and bracing was introduced in addition to the resistive touch selection to counter these issues on the aviation flight deck (Cockburn et al., 2017; Cockburn et al., 2019; Orphanides & Nam, 2017). Participants stated that they wanted or would have like the aircraft touchscreens to have the touch sensitivity of personal devices, smartphones, tablets, and iPads. This group of participants were divided into two separate groups, one that did not recognize the difference and the other that recognized the difference, but still would have wanted similar touch sensitivity between smartphones, tablets, iPads, and touchscreens. Absent of further development and advances, it appears that this is an area that pilots must become accustomed to and understand when interacting, working, and making selections with touchscreens on the aviation flight deck. Aircraft touchscreen manufacturers, as well as training providers, highlight the differences between touchscreens and personal devices and this is not an unrecognized area or lack of information being provided to the end users.

One other area that was stated by participants, nearly half, was training and training devices when asked to provide ways that interacting and learning touchscreens could be improved. A number of areas were mentioned, how to videos, standard interfaces, selections across platforms, more touch like similarity to iPad and personal devices, having an actual keyboard for typing, and adding touchscreen capability to the DU's, but these were individual responses. The most stated ways were to have more training time, more training applications, especially interactive on personal devices outside of training, emulators, widely available in simulators and an application or device almost exactly like a touchscreen or an actual touchscreen. This data suggests that issues or difficulties interacting, working and making selections with touchscreens can be alleviated or avoided with a higher level of training and training devices for some participants. These issues were mentioned across all the age categories, suggesting that this is an area that is not affected by age, but the limit of training and training devices replicating touchscreens almost exactly. This would appear to be area that can be applied to the four questions that showed statistically significant differences.

**Statistically Significant Quantitative Questions**

Those remaining four quantitative questions that showed a statistically significant difference, two were multiple choice and two were seven-point Likert scale scored. The two multiple choice questions were number 8 and number 17 and number 7 and number 11 were the seven-point Likert scale (Table 12).

Table 12
Quantitative questions approaching and below statistical significance and p value

| | | |
|---|---|---|
| 6. | The touchscreen is intuitive and making selections with tabs and buttons is easy | 0.0525 |
| 7. | Please rank your ability in interacting, working and finding tasks with touchscreens | 0.0041 |
| 9. | I have a difficult time using applications on my smart phone, tablet or iPad | 0.0036 |
| 11. | Please rank your abilities working with new technology, smartphones, tablets and iPads | 0.0199 |
| 14. | Interacting and making selections with the touchscreens was difficult | 0.0523 |
| 17. | I have an easy time learning new things, especially technology, and embrace it | 0.0268 |

The multiple-choice questions provide less refinement than Likert scale questions providing only four answers for selection.  A seven-point scale provides more refinement than a five-point scale (Finstad, 2010).  This does not make these two multiple choice questions any less significant than the other two Likert scale, but provide data that strengthens the alternate hypotheses that age does have an effect on interacting, working and finding tasks with touchscreens and other automation technology.  Only one of the questions, number 7, dealt with the participants ranking their ability in interacting, working, and finding tasks with touchscreens. Two of the questions, number 8 and number 11, dealt with using applications on my smart phone, tablet or iPad and with ranking the participants abilities working with new technology, smartphones, tablets, and iPads.  The last question, number 17, asked participants to assess if they have an easy time with learning new things, especially technology, and that they embrace accomplishing them.

**Conclusions**

The use of a mixed methodological approach provided both quantitative and qualitative data for acceptance of the alternate hypotheses that age does have an effect on interacting, working and finding tasks with touchscreens and other automation technology. Quantitative data is from the four statistically significant questions and supporting data is provided by number 3, number 6, and number 14. Question 3 was not statistically significant, but provides evidence that some of the participants do not feel fully competent interacting, working, and finding tasks with touchscreens. Question 6 and number 14 the calculations were not below 0.05, but rounding to two decimal places were right at 0.05 and approaching statistical significance. These two questions dealt with touchscreens, making selections with tabs, buttons, and the touchscreen being intuitive and interacting and making selections with touchscreens being difficult. The data from these three indicate that some of the participants have issues with touchscreens and support the four statistically significant questions. The results from the four statistically significant questions provide the data that participants' age has an effect on acquiring, learning, and gaining knowledge and interacting and working with touchscreens and other automation technology. The data from the qualitative questions supports the quantitative data that some of the participants had issues and difficulties with interacting, working, and finding tasks with touchscreens. These issues ranged from finding tasks, making selections, or remembering the path to accomplish the task. Not being initially intuitive was mentioned, but this was alleviated with more work using touchscreens. The differences in touch selection, capacitive and resistive, and the differences between touchscreens and personal devices was stated by participants contributing to their issues and difficulties.

This data provided the evidence that the effects of age had an effect on pilot's acquiring, learning, gaining knowledge, interaction and working with touchscreen technology and other automation technology in the age group 60 years old and older. This was the only age group that had statistically significant differences when compared to the age group 18 years of age up to, but not including 40 years of age and the age group of 40 years of age up to, but not including 60 years of age. These results support other research studies that determined older adults have issues with computers and technology (Czaja et al., 2006; Czaja & Chin, 2007; Olson et al., 2011). The data does support the research of Orphanides and Nam (2017) that different age groups interact differently with touchscreens as well as other areas involving touchscreen target and selection size and consideration of the end users (Gao & Sun, 2015; Orphanides & Nam, 2017). Target and selection size in these studies stated particular dimensions that enable all age groups and older adults ease of use and success in interacting and making selections. Comparing touchscreen use to other avionics packages showed no statistically differences and participants stated that touchscreens reduced workload, offered more information, multiple ways to find information and accomplish tasks, and the ability for future advances to be incorporated by software only supporting the research by Stanton et al. (2013).

The data from the participants in the qualitative questions provides guidance on areas that may offer ways to alleviate the results of this study. Participants stated in several questions that interacting, working, and making selections with touchscreens became easier with more training, repetition, practice and use. A number of the participants in the age category 60 years of age and older, as well as the other two categories, stated this in several questions and when responding to issues, difficulties and ranking their abilities. This data suggests that it may be possible to alleviate and possibly eliminate the effects of age having an effect on pilot's acquiring, learning, gaining knowledge, interaction and working with touchscreen technology and other automation technology. One research study stated that older humans have increased attention, controlled processing, alertness, delayed and immediate recall of pictures with training (Ballesteros et al., 2014). In two other research studies it was stated that suggested that training had an effect on changes in executive control functions, memory updating, shifting, and resistance to interference (Green & Bavelier, 2003; Green & Bavelier, 2006).

**Limitations**

The present study provided data that the effects of age had an effect on pilot's acquiring, learning, gaining knowledge, interaction and working with touchscreen technology and other automation technology. Touchscreens are prevalent in normal everyday life and are been incorporated into the aviation flight deck in more aircraft, new and as replacements or additions to avionics packages already in place. One limitation to this study is the time frame was dictated by the constraints of accomplishing it as a thesis for a master's degree. The survey was kept open for as long as possible and had more participants than the minimum of 25 and the target of 50. 55 initially logged onto the survey link, with one pilot declining to participant, six others not answering any question after electing to participant and the remaining 48 answering the survey in varying levels of response. 38 participants answered all the demographic, quantitative and qualitative questions. With a longer time period, additional participation may have been acquired and possibly may have altered the results. The number of pilots elected to participant was high in Gulfstream and Honeywell experience, but other aircraft types and touchscreen manufacturers were represented. The pilots elected to participate were from all the categories listed for type of flying, Part 121, Part 135, Corporate, GA, and Military so this did not become a limitation to the study being centered on one touchscreen type or not all segments of aviation.

Another limitation that resulted from the time frame was the three follow up questions that asked for additional insights, knowledge, data and information from the participants. The survey was conducted online with esurveycreastor.com and the three follow up questions were part of that survey link. While there was a significant number of pilots that participated the majority of the answers for those questions, particularly the one asking specifically for more information, data or thoughts, were simple one word, several words or several sentence responses. There were some significant detailed answers from pilots, but the researcher was anticipating a higher level of those type of responses. Initially, the researcher was planning on following up the survey with phone interviews from willing participants, but that was not feasible due to the limited time frame. Future research can be tailored for either in person participation or, if online, with a follow up phone interview. Researchers would be able to ask questions tailored to previous responses from participants to gather additional information, insights and knowledge. They would be able to clarify previous answers or ask questions to refresh the participants recollections of their answers to provide additional information, insights or clarity. In person or a follow up phone discussion would enable the researcher to ask participants what they were thinking about when answering questions and during discussion the participants may be aware of any inconsistencies with their answers or spur further thought on that question (Hartley & Betts, 2010).

**Recommendations**

Future studies can examine the results of this study as well as build on it in different ways and areas. Focusing exclusively on touchscreens on the aviation flight deck may results in different data that would confirm or refute the results of the present study. From this future research other areas or results may be found that additional research can be focused on. Tailoring the research to touchscreens on the aviation flight deck exclusively may change the results that were found in the present study. By incorporating smartphones, tablets, iPads, and new technology in the questions introduce several topics into the questions which research suggest may affect the results (Hartley, 2013). In this vein, negatively worded questions could have an effect on the results as has been stated in research since it is difficult in English to write the question worded exactly positively and negatively (Hartley, 2013).

Future studies could incorporate a touchscreen application, replication of a touchscreen or actual touchscreens for examination with participants. Actual data could be measured by participants responses for statistical calculations and more refined results than from Likert scale scored questions. The research would be able to be conducted in a controlled environment and conditions. It would also allow for in person discussion and follow up questions that would provide more in-depth data and information than could be achieved from an online survey with follow up questions as part of the survey. A study of this magnitude may allow for renumeration to the pilots that my garner more participation.

Different manufactures of aviation touchscreen products could be included in future studies and participants would be assessed on their interactions, working and finding tasks on the different ones. The results and data from the research would give insight into the intuitiveness, ease of use and transparency of the touchscreens. The study could examine if one particular touchscreen was more suited to one age group compared to another, or if the differences were negligible between them. This type of study could lead to the further refinement in the presentation and interfaces of touchscreens.

Future studies with touchscreens could also include training on them in the research. A study could examine participants interacting, working and accomplishing tasks with touchscreens with little or no training. Training on the touchscreens accompanied by practice could then be accomplished and the two results compared. Incorporating training into additional studies would confirm or refute the researcher suggestion that training would alleviate or eliminate the effects of age having an effect on pilot's acquiring, learning, gaining knowledge, interaction and working with touchscreen technology and other automation technology. The data of the qualitative answers from the participants from all age categories stated that training, repetition, and practice made interacting, working and accomplishing tasks with touchscreens easier. Additionally, participants stated that repeated practice and use of touchscreens made interacting, working and accomplishing tasks with touchscreens easier. Participants mentioned that infrequent use of aviaton touchscreens in operations were an area of concern. Aviaton operations and pilots have different levels of flying and Part 121 and Part 135 pilots generally fly more often than Corporate, GA, and Military pilots. Pilots from different types of operations could be mixed in studies to provide data on possible differences in their interacting, working and accomplishing tasks and how great or little that has on performance.

One additional area that the researcher noted and is not related to touchscreens, smartphones, tablets, iPads, and new technology was the different levels of participation in the age group categories. The only age group that elected to participate and answered all the demographic, survey and follow up questions was the 60 years old and older. As noted by the researcher, the number of participants in the age group 18 years old up to, but not including 40 years of age had only six participants finishing after 12 had started. In the age category of 40 years old up to, but not including 60 years of age, 26 had started the demographics and questionnaire and 24 finished the first section of the questionnaire representing just a little more than 9% dropout rate. This extended to answering the qualitative questions on the level of input, information, insights, and data. More input, feedback, data, information, and insights were provided by more participants in the age category of 40 years old up to, but not including 60 years of age, and 60 years old and older. There was input, feedback, data, information, and insights in the age group 18 years old up to, but not including 40 years of age, but this was limited to one or two of the participants in the questions. Future research could examine this difference that the present study finds and possibly determine a reason for this. It could be that the present study was not designed in a user-friendly way or possibly inadvertently tailored by the researcher to the age category that the researcher is in. For the input of the qualitative answers this may be an issue along generational lines, where younger adults have grown up using technology more and as a natural occurrence, smartphones, texting, short messages service (SMS), emojis, slang, than their older counterparts. Older adults grew up without this technology, especially smartphones and cellphones and are more use to longer written communication and direct verbal conversation. There appears to be a significant difference in the response rate between the age categories that future research could determine the reason. This may apply to age categories regardless of research topic and may be characteristic of each group.

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Appendix A

EMBRY-RIDDLE Aeronautical University FLORIDA | ARIZONA | WORLDWIDE

Xx Xxxx 2020

# Human Subject Protocol Application

Campus: **Worldwide** College: **Online**

Other Institution Name & Address:

Applicant: **Norman Kemble** Degree Level: **Masters**

ERAU ID: **2427722** ERAU Affiliation: **Student**

Project Title: **A Mixed Methodology Study of the Effects of age, Touchscreens, New Technology, Automation, and Interactions on Pilot Performance**

Principal Investigator: **Norman Kemble**

Submission Date: **01/16/2020**

Beginning Date: **02/10/2020**

Type of Project: **Survey**

Type of Funding Support (if any): **No**

Questions:

1. **Background and Purpose**: Briefly describe the background and purpose of the research.

   The purpose of this study is to examine pilots' interactions with new technology touchscreens that are being introduced on the flight decks and if age has any effect. This study aims to examine pilot age and the ease or difficulty interacting and working with touchscreens and in acquiring working knowledge and understanding of them. This research will use a demographic and background gathering survey and a questionnaire to collect relevant data regarding pilots' use of touchscreens demographically by age.

2. **Time**: Approximately how much time will be required of each participant?

It will take approximately 5 minutes to complete the demographics survey and 10 minutes to complete the questionnaire for a total of approximately 15 minutes.

3. **Design, Procedures, Materials and Methods**: Describe the details of the procedure(s) to be used and the type of data that will be collected.

   Participants are recruited through an online newsletter, Flight Safety Information, published by Carl Lewis and Associates, will be directed to an online survey site, esurveycreator.com. Esurveycreator.com will publish the survey and provide a dedicated link for the survey for the participants to access. Participants can decide to give consent to participate in the study. Those who give consent, will be presented the online demographic and then the questionnaire. The online questionnaire asks participants to evaluate the ease and difficulty of interacting and working with touchscreens. The participants evaluate the time to gain knowledge and be comfortable with touchscreens as well as the opportunity to provide insight and information in their own words.

4. **Measures and Observations**: What measures or observations will be taken in the study?

   Age, gender, education, ethnicity, and experience with the applications will be collected as demographic information. Participant's interaction, using and knowledge of touchscreens will be measured using a Likert scale. Open ended questions allow the participants to contribute insight and knowledge in their own words.

4b. **If any questionnaires, tests, or other instruments are used, provide a brief description**.

Pilots' Perceptions of Touchscreens: The demographic survey and the questionnaire gathers data on pilot's interaction, working and knowledge using touchscreens on the aviation flight deck along age categories.

5. **Participant Population and Recruitment Procedures**: Who will be recruited to be participants and how will they be recruited. Any recruitment email, flyer or document(s) must be reviewed by the IRB. Note that except for anonymous surveys, participants must be at least 18 years of age to participate.

   Up to 50 participants will be recruited for this study with a minimum of 25 for this study. Participants need to be pilots, 18 years or older, that use touchscreens on the aviation flight deck and will be recruited using an online research pool. Participants can choose when to access, agree and complete the study.

6. **Risks and Discomforts**: Describe any potential risks to the dignity, rights, health or welfare of the human subjects. All other possible options should be examined to minimize any risks to the participants.

   The risks of participating in this study are no greater than what is experienced in daily life.

7. **Benefits**: Assess the potential benefits to be gained by the subjects as well as to society in general as a result of this project.

   While there are no benefits to the participant, the participants will benefit indirectly in their professional field and the knowledge that their time and effort may contribute to the future design of technology and the field of Human Factors in general. The results of this research may help practitioners better understand pilots' interactions, work and knowledge of touchscreens and the effect of age.

8. **Informed Consent**: Describe the procedure you will use to obtain informed consent of the subjects. How and where will you obtain consent? See Informed Consent Guidelines for more information on Informed Consent requirements.

   The informed consent will be presented to participants at the beginning of the online survey. Participants will indicate they have read the consent form and agree to participate by selecting "Yes" to "Agree" on the consent form page. Those who do not consent to the study will not continue to participate.

9. **Confidentiality of Records**: Will participant information be anonymous (not even the researcher can match data with names), confidential (Names or any other identifying demographics can be matched, but only members of the research team will have access to that information. Publication of the data will not include any identifying information.), or public (Names and data will be matched and individuals outside of the research team will have either direct or indirect access. Publication of the data will allow either directly or indirectly, identification of the participants.)

   Anonymous

9b. **Justify the classification and describe how privacy will be ensured/protected.**

Individual information will be protected in all data resulting from this study and access will be by the researcher only. All data will be in digital form with access by the researcher only. Responses to this survey will be anonymous. No personal information will be collected other than basic demographic descriptors. The online survey system will not save IP addresses or any other identifying information. In order to protect the anonymity of participant responses, they will be kept in a password-protected file on a password-protected computer. No one other than the researcher will have access to any of the responses. Information collected as part of this research will not be used or distributed for future research studies.

10. **Privacy**: Describe the safeguards (including confidentiality safeguards) you will use to minimize the risks. Indicate what will happen to data collected from participants that choose to "opt out" during the research process. If video/audio recordings are part of the research, please describe how that data will be stored or destroyed.

    All data will remain anonymous, and no name will be associated with any participant's data. Data from those who choose to opt out during the study will be deleted. Data in digital form will be keyed on an external USB in a locked box.

11. **Economic Considerations**: Are participants going to be paid for their participation?

    No

By submitting this application, you are signing that the Principal Investigator and any other investigators certify the following:

1. The information in this application is accurate and complete
2. All procedures performed during this project will be conducted by individuals legally and responsibly entitled to do so
3. I/we will comply with all federal, state, and institutional policies and procedures to protect human subjects in research 4. I/we will assure that the consent process and research procedures as described herein are followed with every participant in the research
5. That any significant systematic deviation from the submitted protocol (for example, a change in the principal investigator, sponsorship, research purposes, participant recruitment procedures, research methodology, risks and benefits, or consent procedures) will be submitted to the IRB for approval prior to its implementation
6. I/we will promptly report any adverse events to the IRB

Electronic Signature:

Norman Kemble

Appendix B

# INFORMED CONSENT FORM

## A Mixed Methodology Study of the Effects of age, Touchscreens, New Technology, Automation, and Interactions on Pilot Performance

### Purpose of this Study

The purpose of this study is to examine pilots' interactions with new technology touchscreens that are being introduced on the flight decks. Touchscreens combine all functions needed for flight, performance, navigation, flight planning and communications into one device. These are located across the flight deck in multiple locations for easy access. The researcher is asking you to take part in this study for the purpose of ascertaining the ease or difficulty interacting and working with touchscreens and in acquiring working knowledge and understanding of them. During this study, you will be asked to complete a brief online survey about your opinions concerning the ease and difficulty of interacting and working with touchscreens and acquiring working knowledge and understanding. The completion of the survey will take approximately ten minutes and completion of a Demographics survey will take approximately five minutes.

### Eligibility

To be in this study, you must be a pilot that uses touchscreens on the aviation flight deck and be 18 years of age or older.

### Risks or discomforts

The risks of participating in this study are no greater than what is experienced in daily life.

### Benefits

There are no benefits to you as a participant, you will benefit indirectly through in your professional field and with the knowledge that your time and effort may contribute to the future design of technology and the field of Human Factors in general. Your assistance in this research may help practitioners better understand and gauge the ease and difficulty of pilots' acquiring knowledge and understanding interacting with touchscreens.

### Confidentiality of records

Your individual information will be protected in all data resulting from this study. Your responses to this survey will be anonymous. No personal information will be collected other than basic demographic descriptors. The online survey system will not save IP address or any other identifying information. In order to protect the anonymity of your responses, I will keep your responses in a password-protected file on a password-protected computer. No one other than the researcher will have access to any of the responses. Information collected as part of this research will not be used or distributed for future research studies.

**REQUIRED STATEMENT FOR INTERNET RESEARCH THAT USES SENSITIVE INFORMATION**

All survey responses that the investigator receives will be treated confidentially and stored on an encrypted laptop, accessible only to the author and backed up on an encrypted USB drive stored in a box under lock and key. The author is the only one with the keys. However, given that the surveys can be completed from any computer (personal, work, school, etc.), we are unable to guarantee the security of the computer on which you choose to enter your response. As a participant in this study, the author wants you to be aware that certain "keylogging" software programs exist that can be used to track or capture data that you enter and/or websites that you visit. Information collected as part of this research will not be used or distributed for future research studies.

**Compensation**

There is no compensation offered for taking part in this study.

**Contact**

If you have any questions or would like additional information about this study, please contact Norman Kemble, kemblen@my.erau.edu, or the faculty members overseeing this project, Dr. Clint Balog, balogc@erau.edu and Dr. Dennis Vincenzi, vincenzd@erau.edu. For any concerns or questions as a participant in this research, contact the Institutional Review Board (IRB) at 386-226-7179 or via email teri.gabriel@erau.edu.

**Voluntary Participation**

Your participation in this study is completely voluntary. You may discontinue your participation at any time without penalty. Should you wish to discontinue the research at any time, no information collected will be used and will be deleted and the records destroyed.

**CONSENT**

By checking YES to AGREE below, I certify that I am a pilot over the age of 18 years old that interacts and works with touchscreens on the aviation flight deck, understand the information on this form, and voluntarily agree to participate in the study.

If you do not wish to participate in the study, simply close the browser or check NO to DISAGREE which will direct you out of the study.

Please print a copy of this form for your records. A copy of this form can also be requested from Norman Kemble, kemblen@my.erau.edu.

☐ YES

☐ NO

# Appendix C

## Demographic Background Information

1. What is your age: 18-39 ☐ 40-59 ☐ 60 or above ☐
2. What is your gender: Female ☐ Male ☐
3. What is the highest license you hold: ATP ☐ Commercial ☐ Private ☐ Other ☐
4. Instrument rating: Yes ☐ No ☐
5. Type rating: Yes ☐ No ☐ More than 2-4 ☐ More than 5 or more ☐
6. Are you currently flying: Yes ☐ No ☐
7. What aircraft: Airbus ☐ Bombardier ☐ Boeing ☐ Cessna ☐ Dassault ☐ Gulfstream ☐ Other ☐
8. What is your total flight time: under 1000 ☐ 1001-5000 ☐ 5001-10000 ☐ Over 10000 ☐
9. Is flying your primary job: Yes ☐ No ☐
10. Type of flying Part 121 ☐ Part 135 ☐ Corporate ☐ GA ☐
11. Do you have and use a smartphone: Yes ☐ No ☐
12. Do you have and use a personal tablet/iPad: Yes ☐ No ☐
13. Do you use a work tablet/iPad: Yes ☐ No ☐
14. What type of touchscreen do you use flying: Honeywell ☐ Rockwell Collins ☐ Other ☐
15. How long have you been using touchscreens: Less than 1 year ☐ 1-3 years ☐ Longer than 3 years ☐

Appendix D

**Questionnaire**

1. I am one of the first to buy new products, especially technology

   Most of the Time ☐ Some of the Time ☐ Seldom ☐ Never ☐

2. I am competent with smart phones, tablets and iPads

   Extremely ☐ Very ☐ Moderately ☐ Slightly ☐ Not at all ☐

3. I am competent with the touchscreens used on my aircraft

   Exceptional ☐ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor ☐ Very Poor ☐

4. How easy or difficult is working with smartphones, tablets, iPads, touchscreens and new technology

5. I set up, configure, add applications and programs easily on my smartphone, tablet, iPad and computer

   Yes ☐ I have a friend/relative do it ☐ I have the business I bought it from do it ☐ No ☐

6. The touchscreen is intuitive and making selections with tabs and buttons is easy

   Extremely ☐ Very ☐ Moderately ☐ Slightly ☐ Not at all ☐

7. Please rank your ability in interacting, working and finding tasks with touchscreens

| Far Above | Moderately Above | Slightly Above | Met Expectations | Slightly Below | Moderately Below | Far Below |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

8. What worked well for you with learning, interacting and making touchscreen selections

9. I have a difficult time using applications on my smart phone, tablet or iPad

| Most of the Time | Some of the Time | Seldom | Never |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

10. I have a difficult time working with the touchscreens on my aircraft

| Extremely | Very | Moderately | Slightly | Not at all |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

11. Please rank your abilities working with new technology, smartphones, tablets and iPads

| Far Above | Moderately Above | Slightly Above | Met Expectations | Slightly Below | Moderately Below | Far Below |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

12. What were some of the questions or difficulties you had working with the touchscreens?

13. I have a hard time learning new things, especially technology, and try to avoid it

| Most of the Time | Some of the Time | Seldom | Never |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

14. Interacting and making selections with the touchscreens was difficult

| Extremely | Very | Moderately | Slightly | Not at all |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

15. Compared to learning other new technology the total amount of time it took me learning to use and interact with touchscreens left me

| Very Satisfied | Moderately Satisfied | Slightly Satisfied | Neutral | Slightly Dissatisfied | Moderately Dissatisfied | Very Dissatisfied |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

16. What do you like or dislike about working with technology, smartphones, tablets, iPads and touchscreens?

17. I have an easy time learning new things, especially technology, and embrace it

| Most of the Time | Some of the Time | Seldom | Never |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

18. I can easily find and navigate between the performance, flight planning, communications and the systems on the overhead panel touchscreens

| Extremely | Very | Moderately | Slightly | Not at all |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

19. Please rank the difficulty learning, interacting and using touchscreens compared to other avionics packages that you have used

| Far Above | Moderately Above | Slightly Above | Met Expectations | Slightly Below | Moderately Below | Far Below |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

20. What was difficult with learning, interacting and making touchscreen selections Why

Appendix E

1. Are there any ways that interacting and learning touchscreens could be improved?

2. Would you make any changes to how the touchscreens work, selections, layers, interface?

3. Is there any additional information, data or thoughts that you have?

Appendix F

**DEBRIEFING FORM**

The purpose of this study is to examine if pilot age effects working with touchscreens and new technology on the aviation flight deck. This has been relatively recent and there have been very few studies on them. Previous studies have focused on the viability of touchscreens on the aviation flight deck, ergonomic issues, vibration and turbulence and the pilot's ability to correctly select the desired task. This study is one of the first to examine pilot age and working with touchscreens.

If you have any questions or would like additional information about this study, please contact Norman Kemble, kemblen@my.erau.edu, or the faculty members overseeing this project, Dr. Clint Balog, balogc@erau.edu and Dr. Dennis Vincenzi, vincenzd@erau.edu. For any concerns or questions as a participant in this research, contact the Institutional Review Board (IRB) at 386-226-7179 or via email teri.gabriel@erau.edu.

# Appendix G

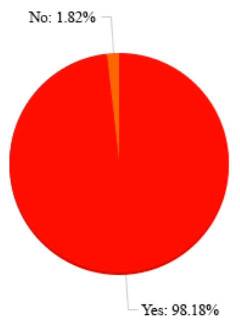


Figure 16. Total participants

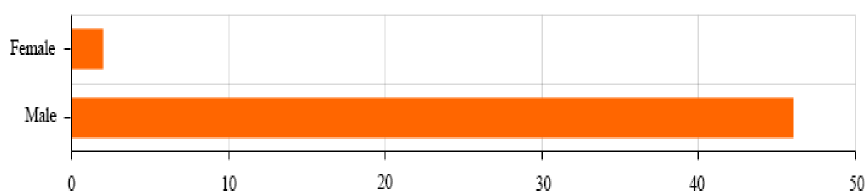


Figure 17. Gender breakdown

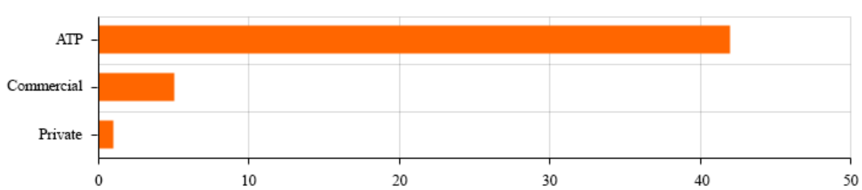


Figure 18. Highest license

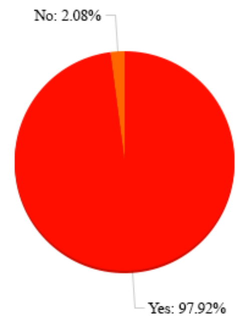


Figure 19. Instrument rating

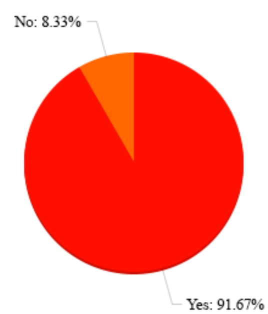


Figure 20. Currently flying

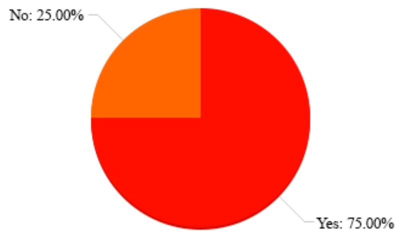


Figure 21. Flying primary job

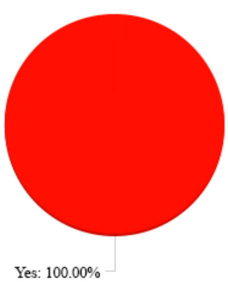


Figure 22. Own and use a smartphone


Figure 23. Own and use a personal tablet/iPad

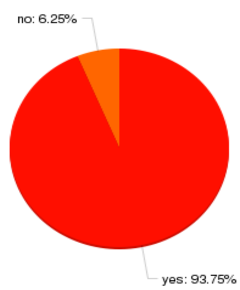


Figure 24. Use a work tablet/iPad

Appendix H

| | Quantitative questions | p |
|---|---|---|
| 1. | I am one of the first to buy new products, especially technology | 0.6339 |
| 2. | I am competent with smart phones, tablets and iPads | 0.4534 |
| 3. | I am competent with the touchscreens used on my aircraft | 0.0707 |
| 5. | I set up, configure, add applications and programs easily on my smartphone, tablet, iPad and computer | 0.4719 |
| 6. | The touchscreen is intuitive and making selections with tabs and buttons is easy | 0.0525 |
| 7. | Please rank your ability in interacting, working and finding tasks with touchscreens | 0.0041 |
| 9. | I have a difficult time using applications on my smart phone, tablet or iPad | 0.0036 |
| 10. | I have a difficult time working with the touchscreens on my aircraft | 0.4177 |
| 11. | Please rank your abilities working with new technology, smartphones, tablets and iPads | 0.0199 |
| 13. | I have a hard time learning new things, especially technology, and try to avoid it | 0.2003 |
| 14. | Interacting and making selections with the touchscreens was difficult | 0.0523 |
| 15. | Compared to learning other new technology the total amount of time it took me learning to use and interact with touchscreens left me | 0.4291 |
| 17. | I have an easy time learning new things, especially technology, and embrace it | 0.0268 |
| 18. | I can easily find and navigate between the performance, flight planning, communications and the systems on the overhead panel touchscreens | 0.4186 |
| 19. | Please rank the difficulty learning, interacting and using touchscreens compared to other avionics packages that you have used | 0.4655 |

# Appendix I

| Qualitative questions | | p |
|---|---|---|
| 1. | I am one of the first to buy new products, especially technology | 0.6339 |
| 2. | I am competent with smart phones, tablets and iPads | 0.4534 |
| 3. | I am competent with the touchscreens used on my aircraft | 0.0707 |
| 5. | I set up, configure, add applications and programs easily on my smartphone, tablet, iPad and computer | 0.4719 |
| 6. | The touchscreen is intuitive and making selections with tabs and buttons is easy | 0.0525 |
| 7. | Please rank your ability in interacting, working and finding tasks with touchscreens | 0.0041 |
| 9. | I have a difficult time using applications on my smart phone, tablet or iPad | 0.0036 |
| 10. | I have a difficult time working with the touchscreens on my aircraft | 0.4177 |
| 11. | Please rank your abilities working with new technology, smartphones, tablets and iPads | 0.0199 |
| 13. | I have a hard time learning new things, especially technology, and try to avoid it | 0.2003 |
| 14. | Interacting and making selections with the touchscreens was difficult | 0.0523 |
| 15. | Compared to learning other new technology the total amount of time it took me learning to use and interact with touchscreens left me | 0.4291 |
| 17. | I have an easy time learning new things, especially technology, and embrace it | 0.0268 |
| 18. | I can easily find and navigate between the performance, flight planning, communications and the systems on the overhead panel touchscreens | 0.4186 |
| 19. | Please rank the difficulty learning, interacting and using touchscreens compared to other avionics packages that you have used | 0.4655 |

| Qualitative follow up questions | |
|---|---|
| 1. | Are there any ways that interacting and learning touchscreens could be improved? |
| 2. | Would you make any changes to how the touchscreens work, selections, layers, interface? |
| 3. | Is there any additional information, data or thoughts that you have? |

# Appendix J

1. I am one of the first to buy new products, especially technology

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| 40-59 | Most of the Time | Some of the Time | Seldom | Never |
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2. I am competent with smart phones, tablets and iPads

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3. I am competent with the touchscreens used on my aircraft

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| 40-59 | Exceptional | Excellent | Very Good | Good | Fair | Poor | Very Poor |
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| 60 and above | Exceptional | Excellent | Very Good | Good | Fair | Poor | Very Poor |
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5. I set up, configure, add applications and programs easily on my smartphone, tablet, iPad and computer

| 18-39 | Yes | I have a friend/relative do it | I have the business I bought it from do | No |
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| 60 and above | Yes | I have a friend/relative do it | I have the business I bought it from do it | No |
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6. The touchscreen is intuitive and making selections with tabs and buttons is easy

| 18-39 | Extremely | Very | Moderately | Slightly | Not at all |
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7. Please rank your ability in interacting, working and finding tasks with touchscreens

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| 60 and above | Far Above | Moderately Above | Slightly Above | Met Expectations | Slightly Below | Moderately Below | Far Below |
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9. I have a difficult time using applications on my smart phone, tablet or iPad

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10. I have a difficult time working with the touchscreens on my aircraft

| 18-39 | Extremely | Very | Moderately | Slightly | Not at all |
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| 60 and above | Extremely | Very | Moderately | Slightly | Not at all |
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11. Please rank your abilities working with new technology, smartphones, tablets and iPads

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13. I have a hard time learning new things, especially technology, and try to avoid it

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14. Interacting and making selections with the touchscreens was difficult

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15. Compared to learning other new technology the total amount of time it took me learning to use and interact with touchscreens left me

| 18-39 | Very Satisfied | Moderately Satisfied | Slightly Satisfied | Neutral | Slightly Dissatisfied | Moderately Dissatisfied | Very Dissatisfied |
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| 40-59 | Very Satisfied | Moderately Satisfied | Slightly Satisfied | Neutral | Slightly Dissatisfied | Moderately Dissatisfied | Very Dissatisfied |
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| 60 and above | Very Satisfied | Moderately Satisfied | Slightly Satisfied | Neutral | Slightly Dissatisfied | Moderately Dissatisfied | Very Dissatisfied |
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17. I have an easy time learning new things, especially technology, and embrace it

| 18-39 | Most of the Time | Some of the Time | Seldom | Never |
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| 40-59 | Most of the Time | Some of the Time | Seldom | Never |
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| 60 or above | Most of the Time | Some of the Time | Seldom | Never |
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18. I can easily find and navigate between the performance, flight planning, communications and the systems on the overhead panel touchscreens

| 18-39 | Extremely | Very | Moderately | Slightly | Not at all |
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| 40-59 | Extremely | Very | Moderately | Slightly | Not at all |
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| 60 or above | Extremely | Very | Moderately | Slightly | Not at all |

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19. Please rank the difficulty learning, interacting and using touchscreens compared to other avionics packages that you have used

| 18-39 | Far Above | Moderately Above | Slightly Above | Met Expectations | Slightly Below | Moderately Below | Far Below |
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| 40-59 | Far Above | Moderately Above | Slightly Above | Met Expectations | Slightly Below | Moderately Below | Far Below |
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| 60 or above | Far Above | Moderately Above | Slightly Above | Met Expectations | Slightly Below | Moderately Below | Far Below |
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Appendix K

4. How easy or difficult is working with smartphones, tablets, iPads, touchscreens and new technology

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|---|---|
| 18-39 | |
| | Very |
| | Moderately difficult to learn a new system without the proper support and training. |
| | Easy |
| | Easy once you understand the swipeology. |
| | Easy |
| | No issues |
| | It is not difficult to work with touchscreens in the cockpit, especially if one knows how to them. If a pilot is having trouble using or navigating one, then more time should be spent on the ground learning tp use them. |
| | Naturally it takes a small amount of time to get used to new software or updates, but otherwise it's easy. |
| 40-59 | |
| | Depends on how much you engage it and learn it. It’s like any OS. It has a lot of functionality built in, however the end user determines how much they want to get into it. |
| | Very easy |
| | Very easy as long as I practice and stay current with all features and their locations. |
| | Very easy |
| | Phones and tablets are easy because you literally use them all the time. Aviation touch screens can be more of a challenge because even if you fly regularly, not nearly as much time is spent with the interface as your phone or tablet. |
| | It’s very easy. |
| | Not at all. |
| | Easy when the tech is good. |
| | Easy depending on quality of the interface or application. |
| | Very easy to use. Understanding systems logic and menu logic is key |
| | Very, very easy. |
| | Fairly easy |
| | Not difficult |
| | Easy |
| | I find it fairly easy and enjoy learning more efficient ways to use the screens. |
| | Depends on the interface and platform used to present information. Some automation manufacturers make the interaction more intuitive than others. |
| | Very easy |

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| | I do not find it difficult to work this technology. Smartphones and iPads are easy to use but I'm not sure I know all the different functionalities to maximize the technology of these items. However, with the aircraft touch screens, I have had a lot experience in learning and teaching this technology and find it very easy to use and feel I now majority of functionality. |
| | Easy. As an industry leader the Apple products have seemed to set the interface standard/norms. Other OEMs have generally conformed to similar gesture engines which makes using them quite easy. |
| | Easier the more you use. |
| | Very |
| | Fairly easy; most touchscreen technology seems to be pretty intuitive. |
| | Not difficult |
| | Easy for the most part. |
| | very easy |
| | I'm very comfortable with this technology. |
| 60 and above | |
| | I find it mostly comfortable. I don't hesitate to learn the technology . Once I learn the basic technology for the functions I need/use, I feel comfortable. If I need to use a new function I am generally eager to learn it and expand my capability. Once learned I am fully comfortable with the technology. |
| | learn it, use it, be happy. It was easy for me |
| | Not very difficult to adapt to the new technology. The biggest challenge is learning where the information is located within the touchscreen vs having push button MCDU ‘s. |
| | In the beginning |
| | Very easy |
| | Most apps I use are very simple. The latest programing is usually very user friendly. If Apps have bad reviews because of ease of use they get bad rating and are not used. |
| | It’s something I have had to get used to. I miss push buttons |
| | Easy |
| | Easy |

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|---|---|
| | Smart Phones and iPad experience and satisfaction level / ease of use, etc., is dependent on the amount of usage (e.g., the more you use it the more familiar and adept you become with the device). It is also dependent on how much effort you put into taking the extra time to learn more of the capabilities of such devices.; ; As for touchscreens and other new technology being installed in todays modern aircraft, your level of capability / satisfaction / ease of use will initially come from proper training on the devices, followed by practice, practice, practice with these devices. Likewise as stated above, the more you use these devices the more adept you become. For pilots, those who fly often, approaching airline type of annual flight time, will find themselves becoming very adept and at ease with their usage. Contrarily, for those pilots who fly infrequently, accumulating maybe 200 hours flight time annually, will find themselves always having to 'relearn' how to correctly enter flight plans, performance data, request flight plan or weather download, etc. Pilots in this latter case will be best served by self-maintaining proficiency in the devices usage.; ; Another area of concern, for foreign pilots, would be the individual pilot's proficiency in understanding and being fairly fluent in the English language. It has been my experience in training pilots from around the world that this level of English language proficiency varies greatly, regardless of any regulatory requirement to maintain at least a level 4 understanding of the English language. If you cannot readily read and understand the text on the device pages, you will have some difficulty in attaining any sort of proficiency in using this technology.; ; Education (training) and taking the time to practice, practice, practice is the only answer. |

8. What worked well for you with learning, interacting and making touchscreen selections

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|---|---|
| 18-39 | 24. 8. What worked well for you with learning, interacting and making touchscreen selections |
| | Trial and error |
| | Using the touchscreen on a daily basis, being allowed to practice, asking questions of others |
| | Goggling any problems I encountered. |
| | My age. |
| | Finding information quickly |
| | Asking questions if I didn't know how to do something |
| | visually and physically manipulating the touchscreen options |
| 40-59 | |
| | Practice |
| | Desktop trainers |
| | Knowing the features and where they’re located. Reading manuals helps as well. |
| | Copy paste, zoom in/out |

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|---|---|
| | Some instruction followed by extensive use. |
| | Hands on |
| | Easy to adapt |
| | FSIs program kept you interacting with the touchscreen. Total exposure time is the key to being proficient. |
| | Having an iPad emulator for the aircraft touchscreen helped immensely learning at a slow pace without any training pressure or time pressure in the simulator. |
| | Understanding of manufacturer (ie: Garmin) menu and systems logic. For instance, looking at a touch screen home page, it would not make sense to have flight plans under a map page, etc. |
| | Trial and error. |
| | Modeling |
| | Having a iPad based simulation of the touchscreen to practice on |
| | Lots of exposure |
| | Understanding the logic behind the design...for example, for the TSC in the G500/600, understanding the Phase of Flight (POF) logic and how the shortcuts change based on which POF you are in...helps one figure out how to navigate the screens efficiently. |
| | Understanding the structure towards information grouping by repetition and practice. |
| | Hands-on experience is key |
| | In question 5, I can add applications but usually rely on the business to set up and configure. Although, my latest Apple phone was very easy to set-up and configure.; For question 6, the touchscreen was not intuitive at first but it didn't take long before it was intuitive.; What worked best was having someone show me how to interact and where to find options, and then practice and real-life applications. |
| | Simply time exposure. Time spent playing around with the interface. |
| | Learning and understanding the logic that was designed into the layout. |
| | Instruction w people that were proficient. |
| | Doing it. |
| | Repetition |
| | Practice. |
| | self study, using Youtube/Google if more information needed |
| | I am the pilot that wrote the requirements for the Guflstream GVII touchscreens, and I designed the page layouts with a lot of help from electrical engineers and human factors engineers. |
| 60 and above | |
| | Learning from someone who knows, learning from online videos such as YouTube, teaching myself what I can by using the technology offline in an environment where I can not do any harm with mistakes. |
| | repetition |

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| | Developing a base routine for programming to enable muscle memory development. |
| | The FSI app |
| | Development of the touchscreens and their applications. |
| | Recommendations from friends and reading reviews from the app. |
| | A program that allowed me to interact and practice the various expected task |
| | Tutorials |
| | Learning the particular type of gestures. |
| | Having the capability, through being able to use a touchscreen device in a training app on the iPad, as well as in an FTD, to practice all requisite programming one would find having to do on any particular flight. |

12. What were some of the questions or difficulties you had working with the touchscreens?

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|---|---|
| 18-39 | |
| | Occasional crashes |
| | Standard learning curve, once you've done a task a dozen or so times, it's easy. |
| | N/A |
| | I once had a touchscreen glitch so it was very delayed in reacting when I touched buttons on the screen. |
| | Understanding how to complete certain tasks |
| 40-59 | |
| | Few, on occasion the alignment of the selection was hampered by aircraft motion (turbulence). |
| | Sensitivity settings/ multiple types of "swiping" (1 or multiple fingers) etc |
| | Where specific items are located and which route gets the job done in the most proficient manner. |
| | None |
| | learning the infrastructure and how to get to what you need. |
| | None |
| | None |
| | Getting the proper touch to activate the screen. Even at the end of training I found I was pressing too hard or soft or too much print. ; ; It was frustrating to to have to make the selections multiple time to finally take. ; ; I like the ability to have drop downs for frequencies and such, but hard tactile keys are easier to press. |
| | Honeywell Symmetry uses resistive touch screens making quick touch selections not possible. After using phones and tablets all the time, this can be a difficult transition. Also, screens can be slightly slow to respond to changes and don't seem to keep up with the speed of thinking and attempted inputs. Of course, much of this design is deliberate to prevent accidental inputs, but it's difficult to get into a flow with the avionics having to repeat touches (that didn't take) or waiting for pages to respond. |

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| | The only difficulties I've experienced with touchscreens were trying to make a desired selection in turbulence, and processing speeds of the system. Sometimes it takes a bit for the system to process what I am attempting to accomplish. |
| | Getting used to the lack of tactile feedback. |
| | How much pressure to touch screen with |
| | Mostly involving the touch interface requirements, ie how much force is required for how long etc |
| | None |
| | First things first...most of my learning the TSCs was done via On the Job Training. So, it took me a little bit of time to figure out that the POF screens and the way they link to other FMS pages. For example, when loading a STAR and approach to an airfield, it did not dawn on me right away that going to Arrival>FMS, then working your way through the pages is an efficient way to operate.; ; At the same time, some of the early learning on TSCs is somewhat hampered by the lack of the TOLD database. Many screens are not useful...almost negative training. Once TOLD is installed, pilots will need to review pages that they have been glossing over for quite some time. That may be a little difficult. |
| | None |
| | Depending on the method on touch (resistive, capacitive, etc.) can require a bit to get used to |
| | As far as the Airplane touchscreens, just the initial learning phase to figure out where items where and how it worked. Now I feel I'm very strong using these touchscreens. For Apple products, I can do most things, but need help from my adult children or others for more advanced features. |
| | Some apps make it difficult to determine which are data entry fields or make those fields so small as to be unusable with fat man fingers. |
| | Moving too quickly at times. Not giving device time to process my selections before moving on to the next selection. |
| | What limitations /differences were there between devices. |
| | None |
| | Mastering applied pressure to facilitate selections |
| | None. |
| | special in GVII to find the proper combination of pressure an speed to work with the touch screen |

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| | We had to make aircraft touchscreens behave differently than they do in personal electronic devices, to prevent or minimize the likelihood of unintentional activation. The three main design features that do this are: 1) build the touchscreens into a plinth so that there is a finger grip all the way around the touchscreen which allows pilots to put their fingers behind the device and pull-thereby creating tension between the fingers and the shoulder that stabilizes the hand relative to any touchscreen motion that may be happening due to turbulence; 2) use resistive touch technology that requires a specific force to be applied before the screen will register a touch; 3) require a minimum time between "land-on" and "lift-off" of the finger before the touchscreen will register a touch. Items 2 and 3 together cause the pilot to be more deliberate with his finger actions, thereby reducing the likelihood of a missed target. |
| 60 and above | |
| | Most seem to related to where to find, or how to get to, desired page/functions. Once I learn the path, I'm generally okay with repetitive use and with the application itself, especially those applications dealing with topics in my profession, such as aviation, where I know the underlying field. |
| | screen failures |
| | Learning which tabs contained the information that I was looking for. |
| | Remember how to get to screens when I have not used it |
| | Some of the early touchscreens were not very durable. |
| | Just the number of apps available and choosing the right one that fits my needs. |
| | It’s the physical selecting of the desired operation. Sometimes the selection doesn’t take place when you select it. This obviously causes problems as you continue. Also I find it is slower that press buttons. |
| | None |
| | If it's not intuitive, it won't be learned. Many features go unlearned unless you are willing to study and practice these capabilities. |
| | Mainly, where is the information that I currently need located in the myriad pages of information in the device? Finding the page you need is almost half the battle. |

16. What do you like or dislike about working with technology, smartphones, tablets, iPads and touchscreens?

| | |
|---|---|
| 18-39 | |
| | Sometimes I have irrational concerns that my in flight iPads will both die and I’ll be stuck with no pubs. Paper doesn’t need batteries. |
| | Ease of use |
| | If the interface is not intuitive (which most are) it can be difficult to figure out how to work them |
| | I like being on the forefront of the new technology and seeing first hand the advances that have been made in the industry in such a short time |

| | |
|---|---|
| 40-59 | |
| | It keeps me further engaged and provides for a greater situational awareness I feel. Unfortunately the down side is it can provide as a distraction. |
| | I dislike typing on the touch screen keyboards. Prefer multiple pre-canned options |
| | How user friendly they can be assuming that the manufacturer designed them that way. |
| | It would be nice to make a screenshot and drop it with your finger into an email after as attachment, otherwise no problem |
| | Touchscreens are generally intuitive. |
| | It's the future. Sometimes, rarely you have to watch where you touch |
| | See previous answers. |
| | They are inherently distracting due to capability of multiple functions. Example, you turn on iPad with plan to work on banking or bills and end up checking email and other notifications and clicking a link to YouTube. The banking doesn't get done. In aircraft interfaces, it's better due to being purpose built for aircraft functions. The ultimate experience comes down to the quality of the software layout and design. Speed and fluidity of the hardware processing also makes a big difference. Slow response can make touchscreen interaction more cumbersome than traditional hardware buttons in many cases. |
| | I like the ease and simplicity of use of touchscreens. My dislikes are stated in question 12. |
| | Better user interface design. No longer are manufacturers limited to LSKs... They can shape and size buttons/data as appropriate to present the best presentation to the pilot. |
| | The difference in pressure used between aircraft touchscreens and ipads |
| | I like that they can be changed over time with only software updates |
| | I believe you can access data and applications quicker through a touchscreen interface. This make them very useful in the cockpit. |
| | I like the fact that there is a huge amount of functionality in a small space. I also like the fact that there is more color coding than say an older FMS. I like the way graphical depictions can be drawn on a TSC (e.g., takeoff distance versus runway available). I think we are just getting started with the TSC and what we will be able to do with them. ; ; I cannot say there is much, if any, I dislike about the new technology. |
| | New software improvements can effect learner trust in the product if a software change malfunctions or does not work as intended. |
| | Increased capability and flexibility for changes, updates, etc. |
| | I dislike the feeling of trying to get the touchscreen to do something and I'm not sure how to do it. I like that once I'm taught, as long as I use the touchscreens fairly often, it is easy to make the touchscreen do what I want. |
| | Ability to use one device to conduct numerous tasks. |
| | I like the flexibility they offer. Quick access to monitor and/or manipulate multiple systems at a time. |
| | The devices can be configured with new abilities with just software vs hardware changes. |
| | This technology tends to make thing more efficient. |

| | |
|---|---|
| | Easy to navigate selections |
| | It generally makes things easier and makes me more productive. |
| | I like most the easy access, the amount of application, easy access to any information I need in a very short time |
| | Opportunities for new applications and product improvements on the existing designs are boundless. With hardware-based appliances in the cockpit, major upgrades are prohibitively expensive because all of it needs to be replaced. Touchscreens provide a pallet into which we can place any control or display, and it is based on software. Software upgrades are not invasive to the in-service airplanes.; ; Touchscreens allow the use of colors, shapes, and graphics which can provide information in a much more concise way than text. |
| 60 and above | |
| | The convenience, the broad capabilities in one simple location/system, the general ease of use and familiarity of systems that follow standards and protocols. |
| | The best part is when a choice takes you to an appropriate follow on screen based on situation and selection, (not a static choice) |
| | Once I developed the necessary muscle memory I found the new technology to be better and more efficient. |
| | Different platforms |
| | Like the logical interface that leads the user to the most logical solution |
| | Technology changes so quickly makes it difficult keeping up with the latest products. |
| | The largest drawback I find is either something is selected by accident or did not activate when you selected it causing issues further in the download. I also find touchscreens in aircraft lower than conventional buttons |
| | Reduced workload |
| | Very handy. Basically a computer in your hand. |
| | I actually enjoy learning any new technology. I look at it as a challenge to learn how to use these devices proficiently. |

20. What was difficult with learning, interacting and making touchscreen selections Why

| | |
|---|---|
| 18-39 | |
| | Comparable to learning new know and switch avionics. |
| | I had no problems |
| | Navigating to different pages |
| | It's just learning how the pages of the unit interact with each other and learning the location of what you need in the moment |
| 40-59 | |
| | Nothing |
| | Prefer larger touch screen hot buttons |

| | |
|---|---|
| | The most difficult part was finding which route to take in order to complete a task. Their are multiple ways to find and complete several tasks. It's important to find which one works best for you. |
| | - |
| | Not after some initial experience. |
| | The physical touch performance. |
| | With so many functions built into one device (like TSC on GVII aircraft), it can be difficult to remember the path to various functions. Also, flying involves many task interruptions (like new ATC instruction while loading an approach or landing performance). When interrupted during programming, it's easy to lose focus on current task. This can require retracing steps, and starting the task over. Basically, it's hard to task switch under high workload with an advanced touchscreen cockpit layout. It gets easier with practice but it's difficult to learn. Also, there's no common design interface. For example, on a major website from a large vendor, you can generally tell where you are at all times and can navigate backwards and forwards or use the common navigation buttons on the website. With avionics, the layout can change with every new page displayed. There are sometimes hot links to new pages and not always a path to back up or retrace steps. This can lead to confusion about where am I in this multilayered setup sequence. Often we just navigate back to a top layer and work back down if there's no path to go back a page to two. |
| | N/A |
| | None |
| | None |
| | Nothing really besides the initial training, which was easier than other previous aircraft interfaces |
| | no |
| | I do not think it was "difficult". Compared to some older FMS systems where I literally had to memorize certain steps or hunt and peck for selections, the TSCs are much simpler. |
| | Nothing |
| | Nothing significantly different from learning any new FMS. Familiarization with menu selections and locations forms the basis for success. |
| | Just the initial familiarization of figuring out where items where located and selectable. |
| | Remapping my brain from the MCDU architecture to the TSC architecture (where the various functions were located). |
| | Remembering where to find things at first. Learning the logic of the layout resolved this issue. |
| | There wasn't anything that stood out as difficult. |
| | Learning the "architecture" was probably the most difficult aspect, but once I had it figured out it became easy. |
| | Remembering where to find the functions I needed to access was difficult at first |
| | Getting familiar with the architecture. |
| | find the same source of information as known from "classic" aircraft |
| | N/A, since I am the designer. |

| | |
|---|---|
| 60 and above | |
| | Mostly just system navigation until it became familiar. |
| | slow pace of instructors |
| | Again, the biggest challenge was learning the tab location of information. |
| | Just getting to the prover page. |
| | Not difficult at all. |
| | Just like older FMS systems, knowing where the submenus are located is still a memory item. Also, getting too much information on a page makes it hard to locate information. |
| | The most difficult part of learning is finding the available information. Then after you locate it remembering where the information was located when you require it again |
| | Unfamiliarity with the technology |
| | Learning the gestures. |
| | Certain things, like normal flight plan entry, performance info entry, departures & arrivals, etc. were fairly easy, while finding where the correct page for selecting more infrequently used was a challenge. |

1. Are there any ways that interacting and learning touchscreens could be improved?

| | |
|---|---|
| 18-39 | |
| | Widely available simulators. |
| | Not that I'm aware of |
| | Make the interface as intuitive to pilots as possible |
| | More Desktop training, otherwise live practice |
| 40-59 | |
| | More emulators fo practice on digitally |
| | More pre- formatted scenarios on iPads for training |
| | I like them the way they are. |
| | Navigational repetition is critical. In other words, repeatedly performing tasks navigating the logic of the TSC infrastructure. |
| | Yes. Release technology/ swipe is ok. But the iPad type touch would be better. ; ; Bluetooth an iPad. |
| | Yes, many critical programming skills could be learned as a scripted sequence done basically the same way every time. Learning advanced avionics touchscreens often teaches an overwhelming array of options and possible sequences of inputting data. This leads to a dizzying list of possible interface navigation paths to get the same task done. This leads to poor retention and zero muscle memory. |
| | I have no input at this time |
| | Add touchscreen technology to the inboard two DUs. This would minimize CCD input and allow direct manipulation of MFD data. |
| | No |

| | |
|---|---|
| | Just make the touch requirements as close to an iPad as possible, given the turbulent air use requirements |
| | Better training devices. |
| | Make sure one understands the logic behind the design before they start using them. |
| | More training and practice integrated into training curriculums of at least 10 hours. Proficiency matrixes should be created to establish cognitive abilities in targeting how much training time would be applicable per student. |
| | A more interactive PED application would help with familiarization early in the learning process, outside of the normal class, simulator or flight time. |
| | An interactive application that allows "student" to perform different exercises or tasks to get familiar with the touchscreen. |
| | Ipad emulator of device (TSC or Overhead panel) |
| | Make sure to teach the logic behind the layout early and often. |
| | How to videos, or a trainer that was interactive and task based. |
| | A continued emphasis on learning by doing is key. |
| | Better responsiveness of button selections |
| | Can't think of anything. |
| | try and be "open minded" for new technologies |
| | Tell pilots that the touch interaction is necessarily a different experience than they are accustomed to, if they use PEDs. |
| 60 and above | |
| | Standard symbology, procedures across platforms. |
| | no |
| | Have more interactive applications available outside of actual Simulation and Flight Training Devices that can be used to aid in the development of " muscle memory". |
| | Better FSI app on the iPad |
| | Always look for the software to get smarter at anticipating the needs of the user. The time factor and situation factor of the user should be considered in developing applications |
| | On the G700, having a training app, from FSI, that allows you to walk through the pages |
| | Incorporating conventional keyboard for typing |
| | Not sure |
| | Adding a help button that anticipates what the user needs. Many times these help features take you to places you don't need to be at. |
| | Maybe having the capability to actually practice using the real thing, such as having a couple of touchscreens powered and usable, in a separate room, to 'fly' a flight from point A to point B.; ; Yes, I realize this would be a money ($$$) issue, however I've always there is no such thing as too much training. |

2. Would you make any changes to how the touchscreens work, selections, layers, interface?

| | |
|---|---|
| 18-39 | |
| | No |
| | No |
| | No, not really |
| | No |
| 40-59 | |
| | No |
| | No |
| | Not at this time. |
| | Create additional shortcuts. |
| | No |
| | Most interfaces could be greatly simplified by leaving out rarely used functions, and placing an ‘advanced’ selection on each relevant page to access the extra inputs or options. Maintenance type functions could be hidden this way also. I would like to see the interface have more of a website design structure at least with respect to being able to move forwards and backwards and to know where you are at all times. I think capacitive screens should be used with software protections to prevent accidental touches. Similar to phone touchscreen keyboards that autocorrect for miss typed words. |
| | I would require redundancy and lightening fast processors that responded to my selections immediately with no screen freeze. |
| | Touch screen typing is a poor experience for the user. Build a keyboard into the pilot tray to allow for easy text input into the FMS. |
| | No |
| | Just the touch pressure/time requirements as mentioned previously |
| | None |
| | Things I could see improving in the TSCs...screen resolution (higher DPI), easier to use COMM page. |
| | None |
| | Not yet, but there is always opportunity for improvement |
| | none |
| | Quicker processing speed. |
| | Nope |
| | None |
| | No |
| | No. |
| | no |
| | No. |
| 60 and above | |
| | The more intuitive, the better. |
| | configurable layers? Interconnection with iPads? |

| | |
|---|---|
| | None |
| | Not sure |
| | Some information should be moved from current location to different location. |
| | No |
| | Must be more responsive to touch |
| | No |
| | Navigation features that there is no doubt where you are in the program and if you |
| | Nothing I can particularly think of at this time. I think the engineers and designers |

3. Is there any additional information, data or thoughts that you have?

| | |
|---|---|
| 18-39 | |
| | No |
| | No |
| | No |
| | No |
| 40-59 | |
| | No |
| | No |
| | Not at this time. |
| | No |
| | No |
| | The major advantage of touchscreens is the ability to modify interface, change layout, or add and remove functions. It will be interesting to see if this happens very often or if the certification process is too challenging to make any major interface changes. It will also be interesting to see how much OEMs listen to their pilot users and if they make changes based on suggestions or pilot needs. |
| | N/A |
| | It would be nice to increase connectivity between aircraft. ; - broadcast GPS position by bluetooth to iPads to eliminate gps pucks; - allow bluetooth keyboard input from iOS devices to the aircraft; - it would be nice to have access to have an iPad app that is an extension of our FMS (like the Gulfstream Cabin app). This would reduce touchscreen typing and allow direct manipulation of data for ease of use.; - I'm a hobby software developer for iOS. It would be great to have access to FMS APIs to push iPad preflight performance, fuel, and route planning to the aircraft to speed up our FMS initialization. |
| | None |
| | No |
| | No |
| | One of the biggest advantages of the TSC is the ability to modify the functionality and presentation, perhaps more than a traditional FMS.; ; I also believe the look or styling of the TSCs is a positive aspect. |
| | See question 21. |

| | |
|---|---|
| | no |
| | No |
| | none |
| | No |
| | No |
| | None |
| | None |
| | No. |
| | no |
| | No. |
| 60 and above | |
| | No. |
| | no |
| | None |
| | No |
| | Nope |
| | No |
| | None |
| | No |
| | No |
| | Proficiency in using these devices can only come from repetition and practice using them. |