Public Perception of Autonomous Aircraft

by

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ABSTRACT

The aviation industry is considered to be the safest when it comes to transportation of people and property. The standards by which companies provide air transportation are held are very high. Nevertheless, a shortage in the number of pilots exists and companies must look for ways to meet demands. One of the ways to resolve this issue is to introduce unmanned systems on a broader scale – to transport people and property. The public's perception regarding this issue has not been well documented. This survey identified what the public's attitude is towards the use of these systems. One hundred fifty-seven people participated in this survey. Statistical analyses were conducted to determine if participant demographics, previous aviation background, and comfort levels were significantly related to various transportation technologies. Those who were comfortable or uncomfortable with self-driving cars kept their same comfort level for other technologies such as drone delivery services. The survey also revealed that the vast majority of respondents did not feel comfortable being a passenger on fully autonomous aircraft. With an overwhelming percentage of society not comfortable with the idea of there being no pilot for the aircraft, it is important for companies working to implement this technology to pay close attention to the public perception of autonomous aircraft.

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CHAPTER 1

Introduction

Many believe autonomous aircraft will make their way into the aviation industry for the purposes of air carrier operations. It appears that minimal research has been done concerning the public's stance regarding this issue (PytlikZillig, Duncan, Elbaum, & Detweiler, 2018). Research has been conducted on the capabilities of Unmanned Aerial Systems (UASs), but little has been done on the public's perception regarding such systems, mainly on how the public feels about boarding an autonomous passenger carrying aircraft.

Previous studies done on public perception of UAS have focused on relatively smaller UASs and military drones. These studies have proven that word choice when describing UASs has little to no effect on public perception (Clothier, Greer, Greer, & Mehta, 2015; PytlikZillig et al., 2018). Previous research also found that policymakers, UAS manufacturers, and UAS marketers need to focus on stressing the value of these systems (PytlikZillig et al., 2018). The present study aimed to take this information and extend the focus to passenger-carrying UAS.

Some in the aviation industry cite statistics that human factors are a leading cause of aircraft accidents and believe that fully automated aircraft will reduce these accidents to a minimum (Lee, 2015). Pilot's mental health is also raising concerns when it comes to aircraft accidents. Lee (2015) states one reason why these systems are being considered is due to an accident with Germanwings in 2015. A First Officer intentionally crashed an airplane into a mountain. This reintroduced the idea of passenger carrying autonomous vehicles (Lee 2015).

These types of accidents swing the pendulum of this debate towards automation. That said, there is discussion as to whether the pilot should remain in the cockpit for safety, as passenger perception of these systems is most important (Lee, 2015). UASs are rapidly gaining traction, but when it comes to transporting persons, there is substantial contest about whether or not the pilot should stay in the cockpit that takes place (Gates, 2017).

UASs have existed for many years, primarily for military use, whether it be for attacking enemies or surveying them. Affordable Unmanned Aerial Vehicles (UAVs) are able to be purchased at local electronics stores by anyone and can be flown that same day. Though this is a great feat in innovation, there have been numerous problems that have arisen due to these new technologies (Harrison, 2015). These problems include loss of separation with manned aircraft, and privacy of those not involved with the operation of the UAS. With these systems entering into the public sector, this has drawn the attention of policymakers (FAA Modernization and Reform Act of 2012).

The Federal Aviation Administration (FAA) is the government agency that promotes and regulates aviation in the United States. The FAA had been pressured to set regulations for UAS for a prolonged period of time. It was not until Congress passed the FAA Modernization and Reform Act (2012) that the FAA took action. This Act mandated that the FAA, "shall develop a comprehensive plan to safely accelerate the integration of civil unmanned aircraft systems into the national airspace system" (FAA Modernization and Reform Act of 2012). This Act came in response to many concerns not being fully addressed by the FAA, such as law enforcement agencies' use of these systems (Hennigan, 2011). Law enforcement agencies were not the only entities looking to implement these systems.

Companies such as Amazon and Google are attempting to use these systems to make their services more efficient and accessible (Wells & Stevens, 2016). Online shopping has become such an enormous part of everyday life that Amazon is faced with the issue of not being able to deliver their merchandise to their customers fast enough (Amazon, 2015). In order to keep up with demand, these companies are starting to develop small UAS (sUAS) to deliver packages to customers for items as soon as possible. This testing was largely conducted in the United Kingdom due to FAA regulations prohibiting the shopping giant from performing testing in the US. This is a tremendous step in progress towards integrating these automated flying systems into everyday life. With the limitations that Amazon faces with their drones delivering packages to their customers in the US, it can be assumed that new passenger carrying UAS will be met with the same limitations (Wells & Stevens, 2016).

US air carriers are expected to face pilot shortages in the near future due to a large percentage of pilots retiring and a lack of pilots in training to replace them (Bellamy, 2017). It is estimated that by 2023, they plan to have 54,000 pilots retire due to age restrictions in place by the FAA (Mehl, 2016). As a result, companies are researching how to mitigate this issue. Bellamy (2017) describes how Boeing, the largest commercial jet manufacturer in the US, believes the solution lies with UASs. Though there has been some research done regarding perceptions of UASs, current perceptions of larger, passenger carrying UASs remains to be unknown.

A switch to unmanned systems for passenger transport may cause a drastic change in the way people perceive air transportation. If the flying public is not willing to accept such a drastic change in the way they fly currently, it is important for the companies to be able to understand the root of their concerns if they plan on using these types of aircraft in the future (PytlikZillig et al., 2018). Otherwise, the time and money invested in the implementation of these solutions could be a waste.

Automated technology in cars is further along than autonomous aircraft. There have been studies which focus on public opinion of autonomous cars (Hulse, Xie, & Galea, 2018; Reinhart, 2018). This technology is still being researched but is far enough along that people can see them on the roads today (Bensinger & Higgins, 2016).

The purpose of the present study is to determine the current public perception of autonomous, passenger carrying, aircraft. These perceptions are critical for policymakers, aircraft manufacturers, and air carriers in evaluating the public's view on the implementation of this technology. These results will help show where new research needs to be focused in order to resolve or improve public perceptions on new technologies with passenger carrying automated aircraft.

CHAPTER 2

Literature Review

Current State of Unmanned Aerial Systems

UAS is understood by most of the general population as drones. This is largely because the first adaptation of these systems comes from the US military. The military has been using pilotless aircraft since the Civil War with balloons (Cho, 2014). Though these systems were quite rudimentary, this was the dawn of an eventual disruption within the aviation industry. Today, UASs are considerably more complex, leaving the FAA with the job of integrating these systems into the National Airspace System (NAS).

UASs are primarily controlled by the operator via a ground control station. This can be as complex as a computer that can remotely control the UAS, or as basic as a remote controller (Marshall, Barnhart, Shapee, & Most, 2016). That said, with advancements in technology, for those with a greater budget, UASs can be purchased with advanced capabilities. For example, some UASs can be flown via computer software, allowing the operator to set predetermined GPS points with set altitudes, and the UAV will fly this set path with extreme precision, similar to the autopilot in commercial airplanes (Marshall, et al., 2016). Though this technology is quite advanced and helpful in numerous operations, these types of systems are highly limited in their use with the current regulations set in place by the FAA (Operation and Certification of Small Unmanned Aircraft Systems, 2016).

In the summer of 2016 the FAA finalized a set of regulations that applied to sUASs. This set of regulations is under 14 CFR § 107 (Operation and Certification of

Small Unmanned Aircraft Systems, 2016). In part 107 a sUAS is defined as "a small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and efficient operation of the small unmanned aircraft in the national airspace system" (Operation and Certification of Small Unmanned Aircraft Systems, 2016). Though this was a large step for the FAA as it relates to unmanned systems, the FAA still has yet to regulate anything larger than a sUAS.

Due to regulations set by the FAA, most of these systems are unable to fly too far away from the operator. 14 CFR § 107 (2016) states that, "the person manipulating the flight control of the small unmanned aircraft system must be able to see the unmanned aircraft throughout the entire flight…" The FAA is tasked with not only promoting aviation, but also, keeping it as safe as possible. With these competing interests, the FAA has to keep all those affected by operations in the NAS in mind and keep the systems as safe as possible, while also allowing it to progress as an industry.

As for advanced systems such as cargo carrying UAVs, companies are testing their systems to help prove to the FAA that they are reliable enough to be integrated into the NAS (Wells & Stevens, 2016). Amazon's Prime Air website, which is the company's proposed drone service for delivering packages to customers in under 30 minutes with the use of drone, discusses how they will ensure safety:

> Safety is our top priority. Our vehicles will be built with `multiple redundancies, as well as sophisticated "sense and avoid" technology. Additionally, through our private trial in the UK, we will gather data to

continue improving the safety and reliability of our systems and operations. (https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011)

There are other companies that are conducting research and development in this field, and it is a common theme to list safety as a top priority as well as ensuring that there are systems in place to prevent failure (Wells & Stevens, 2016). Amazon (2015) is not simply waiting for the FAA to release rules and regulations on how they want these systems to integrate into the NAS. Instead, they are taking action and proposing their own ideas to help influence the FAA in their decision (Amazon, 2015). For example, currently, according to 14 CFR Part 107 (2016), FAA regulations do not allow UAVs to be operated above 400 feet above ground level (AGL). Amazon has written a paper on how they believe this space should be utilized.

Amazon (2015) believes the current model of airspace management will not meet future sUAS demands, particularly highly-automated, low-altitude commercial operations." This is an example of companies providing the FAA with some influence in their efforts to regulate these systems.

Though FAA regulations are currently limited to sUASs, the way these systems are handled, perceived, and regulated can provide insight into how larger, passenger carrying UASs will be handled in society. With all of this in mind, the users, and those affected by these operations, are largely being left behind. A lot of society's issues with these systems lies within the perceived risk which can be a large contributor to decision making within the human mind. Understanding the perceptions that come with this can help immensely with integration.

Risk Perceptions

Every day, members of the general public take on a certain degree of risk. Whether it be driving in a car, riding the bus, or walking, there is always an amount of risk being taken in these activities. Slovic (1987) states studies of risk perception look into the judgements of society when they are requested to estimate the hazards associated with hazardous technologies or activities.

What is important to humans is how much the benefits outweigh the risks being taken. When humans assess hazards, they typically do so by relying on intuitive judgement, called "risk perception" (Slovic, 1987). Slovic (1987) states the American public is in a search for a zero-risk society and that ultimately hurts our economy. The FAA must take this into consideration when fulfilling its duty of simultaneously promoting aviation as well as ensuring safety.

With new technologies, perception of risk plays a large role in whether one will accept this new technology (Renn & Ortwin, 2013). This is an important aspect to look at when implementing new technologies in order to better help potential users accept the new technology. This becomes just as important when looking at the aviation industry.

With regards to air travel, it is known that statistics of safety are not the only driving force as to why an individual has a fear of flying (Becker, 1990). Becker (1990) states that it has been proven that more people are killed in automobile accidents than in commercial airliner accidents. Yet many still have a perception of risk that is high when discussing flying in an aircraft. This shows that there are other factors playing a role when a passenger is analyzing the risk of whether to fly in an aircraft or not. Becker (1990) focuses on airline marketing in efforts to mitigate passengers' risk perception. This study revealed that when passengers are choosing an airline to fly on, the airline safety record is the major deciding factor. Despite flying by plane being safer than by car, passengers still look for the safest airline to fly with (Becker, 2009). This further proves that risk perception plays a large role in a passenger's decision to fly on an aircraft.

Emotions. Sjöberg (2007) identifies what emotions, positive or negative, are driving participants' perceptions. There are numerous aspects that determine perceptions, and emotions are one of the most important leaders of perception (Sjöberg's, 2007). He surveyed a large population of Swedish people and tested their emotional reactions to various hazards, for example, nuclear waste, cell phones, terrorism, controversial topics. His results found that emotions largely affect perception of risks. For instance, in all examples, fear and anger had a much higher effect than optimism. Based on these results, Sjöberg (2007) emphasized that negative emotions have a much larger effect on how risk is perceived. This shows that not only are fear and anger influencing the perceived risk, but a lack of optimism also has a large influence on this perceived risk.

Terminology. Though emotion plays a role in risk perception, it has been found in other studies that terminology has little effect on these emotions and the public perception of UASs (Clothier et al., 2015). PytlikZillig et al. (2018) states "For example, terminology had no effect on public support, consistent with previous findings. This may suggest UAV developers, policymakers, and users should not waste energy fighting for specific terminology." They continue stating focus should be on how and why these systems will come into use.

PytlikZillig (2018) also found that society has a more positive risk perception when UASs are focused on eliminating threats, as opposed to increasing benefits. They use an example for an entity designing a UAV that will be used to survey fires, they can attain more public support if they highlight how this technology will protect workers and the public from danger. PytlikZillig (2018) claims this is more effective than emphasizing items such as efficiencies and economic savings. For passenger carrying UASs, it might be more beneficial to emphasize the reduced threat of pilot error, instead of focusing on the benefits of potential ticket savings.

Risk perception of technologies. Focusing on the perception of risk helps understand where fears come from with users, or in this case passengers. New technologies very commonly have resistance in adaptation simply because society is more comfortable with the known, as opposed to the unknown, as risk perception is not largely influenced by statistical evidence (Ortwin & Benighaus, 2012). Otway and Winterfeldt (1982) conducted a survey regarding public perception of various technologies. They found that when the public perceives a technology as risky, and statistics prove it to be otherwise, the public seems to be ill-informed. For example, in their study, they found that the group that judged nuclear power to be the riskiest technology on the provided list, also assigned it with the lowest estimated fatality rate out of any of the provided technologies. This shows that technologies that are perceived to be the riskiest are not solely driven by statistical evidence. Much like the findings of Becker (1990).

Otway and Winterfeldt (1982) stated that despite evidence proving that the risk is less than is being perceived, psychological, social, and other beliefs largely impacted participant risk perception. Continuing with the nuclear power risk assessment example from above, participants who saw a positive or negative impact on the economy with nuclear power had a correlated perceived risk. If they saw a negative impact on the economy, the perceived risk was greater than if they perceived a positive impact on the economy. This is an important attribute of risk perception that can be considered. If participants feel unmanned passenger aircraft would negatively impact the economy, they may subconsciously perceive a high level of risk before seeing any statistical evidence in support of this new technology.

Automation in Cars

In 2018, autonomous automobiles saw their first fatal accident. This accident involved a self-driving car and a pedestrian (Reedy, 2018). Reedy (2018) spoke with Andrew Manyard, a professor at the School for the Future of Innovation in Society at Arizona State University, about the future of autonomous transportation:

> At the moment, we know that many of the self-driving cars on the road operate safely under predictable driving conditions. But, when driving conditions are poor, and others on the road behave unpredictably, there is an increased risk of crashes resulting in injury or death.

Manyard makes the point that these vehicles are quite safe until the unpredictable happens (Reedy, 2018). This argument is shared between the autonomy of ground vehicles and the autonomy of aircraft in that attempting to protect against unpredictable situations is difficult.

Now that this technology is present for autonomous vehicles, and on the roads, there is quite a bit of controversy associated with it (Reinhart, 2018). With this in mind, the majority of the public does not appear to consider this technology to be safer. Reinhart (2018) shows the results from a survey asking basic questions about respondent's comfort with self-driving cars. For example, when asked, how likely they were to use fully self-driving cars, fifty-four percent of respondents said they were unlikely to use fully self-driving cars (Reinhart, 2018). This demonstrates that Americans are skeptical when it comes to putting their lives in the hands of an automated computer. Reinhart (2018) continued by asking respondents, how comfortable they would feel riding as a passenger in a fully self-driving car on a daily basis. They responded unlikely at 59%. This number increased when respondents were asked if they felt comfortable sharing the road with these types of vehicles and a strong 62% said they were unlikely to feel comfortable.

Regarding the risk perception associated with autonomous vehicles statistics are not the only factor being considered. Reinhart (2018) compared the negative perception of autonomous vehicles to the same perceptions of cellphones in the year 2000. Twenty-three percent of US adults claimed they would never get a cellphone and today, nearly everyone has one. Reinhart believes this may follow a similar trend with self-driving cars.

Reinhart (2018) found a strong majority were against autonomous vehicles, yet it appears that the industry is headed this way as most major car manufacturers are performing research and development in this technology (Muoio, 2017). This is similar to the aviation industry (Bellamy, 2017). With aviation seeing a shortage in pilots, the manufacturers of aircraft are having to look for new solutions for operating a jet without a pilot. Conversely, the auto industry is seeing a rise in auto accidents and is in a search to innovate new ways to limit these (Bellamy, 2017).

Contrary to Reinhart's (2018) findings, Hulse (2018) found the perception of self-driving vehicles to be positive in a different way. This study was also done via a survey that asked participants residing in the UK their perceptions regarding self-driving vehicles. This not only addressed cars, but also motorcycles, and trains. They found that the perceived risk of autonomous trains was on average "somewhat low," which was actually on the same level as hand driven trains. The results of this survey showed that an autonomous car was perceived to be significantly riskier than a hand driven car. Strangely, when participants were asked their perceived risk when acting as a pedestrian in the vicinity of autonomous cars, they responded that this was less risky than being in the vicinity of hand driven cars (Hulse, et al., 2018).

Pilot Error

A common known fact in aviation is that the majority of accidents and incidents in aircraft are due to pilot error (Helmreich & Foushee, 2010). This is a topic that arises when speaking in favor of automation in aircraft (Lee, 2015). It is common belief that by removing the human aspect of operating any mode of transportation, the number of accidents will be reduced significantly. The idea that removing the pilot from the cockpit will reduce accidents is not as cut and dry as one might believe.

The Performance-based operations Aviation Rulemaking Committee (2013) released in a report regarding the use of automation, that it is important to understand that although most accidents are attributed to pilot error, pilots fly thousands of flights every day safely. Risk is mitigated by these pilots every day and they are able to use their extensive training to maintain a safe operation. Some of the risks mitigated include operational threats such as weather, equipment limitations such as flight management systems, and equipment malfunctions such as engine failures (Performance-based operations Aviation Rulemaking Committee, 2013).

The commonality of error extends to drones as well. In a study conducted by the Air Force in 2007, it was found that from the year 2003 to the year 2006, Predator drone mishaps were primarily caused due to human error (Nullmeyer, Herz, Montijo, & Leonik, 2007). Despite removing the pilot from the cockpit, the Air Force was still having human factors issues. Nullmeyer, et al. (2007) also compared the number of mishaps between early F-16 flights and early Predator drones per 100,000 flying hours. The F-16 is a manned fighter jet that has been used by the military for decades. The Predator is an unmanned drone, that is flown by an operator from a remote location. When comparing the amount of mishaps, it was found mishap rates between the F-16 and the Predator were very close year over year (Nullmeyer et al., 2007). Nullmeyer et al. (2007) compared these two aircraft by the amount of years they had been in service. For example, for the fiscal year of 2003 the Predator saw approximately 10 mishaps per 100,000 flight hours. When comparing this to the F-16 during fiscal year 1981, the F-16 had approximately 8 mishaps per 100,000 flying hours. This can be seen in Figure 1 which shows the number of mishaps per 100,000 hours for the Predator Drones compared to the number of mishaps that occurred in the F-16 per 100,000 flying hours (FY 1977 – 1984) with the same number of years in service.

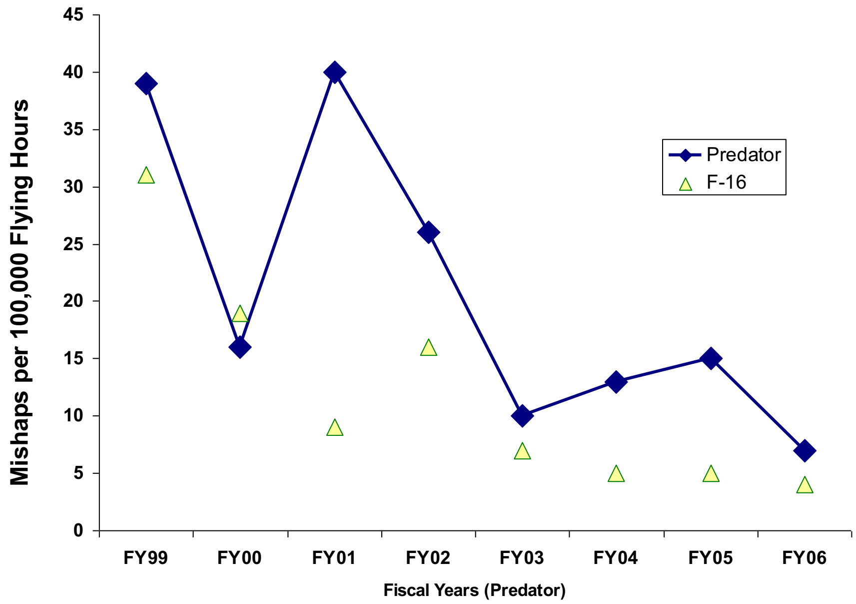

Figure 1. Adapted from "Birdsof Prey: Training Solutions to Human Factors Issues" by Robert T. Nullmeyer, Robert Herz, Gregg A. Montijo, and Robert Leonik, 2007, Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC).

This study shows that it is very difficult to remove the human error associated with mishaps (Nullmeyer et al., 2007). Even when technology becomes more automated, it is quite difficult to remove human error.

Passenger Carrying UAS

The FAA has a plan of how it would like to integrate UAS systems into the NAS (Federal Aviation Administration, 2013). The FAA describes in its UAS integration roadmap, a series of proposed uses for UASs. These examples include, security, search and rescue, broadcasting, the transportation of cargo, and others (Federal Aviation Administration, 2013). One use that is missing from the FAA's list of proposed uses of UAS, the transportation of passengers.

Despite the FAA not having included passenger transport in its proposed use of UAS, the Vice President of Product Development for Boeing believes autonomous, passenger carrying aircraft are a necessity in aviation (Bellamy, 2017). One of the products Boeing is working on is aircraft with, “autonomous taxi and flight control technology, machine learning and high-integrity systems”. Boeing sees the need for this type of technology in order to meet demand from the air carriers. As of 2017, Boeing estimates that there will be the demand for 41,030 aircraft during the next two decades. With this demand for aircraft, a corresponding demand for pilots will occur, specifically 617,000 pilots to operate the 41,030 aircraft. The Boeing Vice President who presented this data does not believe there are currently enough pilots in training to support this demand. Boeing is taking matters into its own hands to combat the upcoming pilot shortage that the aviation industry has been anticipating (Bellamy, 2017). The key challenge Boeing faces when discussing technology is their ability to implement said technology while keeping the safety level where it currently is in the aviation industry.

Boeing is not able to compare themselves to the auto industry which is also currently looking into autonomous systems as discussed above. Bellamy (2017) states that the automotive industry saw a 14% increase in fatalities from 2014 to 2016, while in the aviation industry, scheduled air US transport flights saw zero fatalities in 2016. This means that Boeing is faced with the challenge to not only implement a highly advanced technology in an industry that is getting safer already but do so with having little to no error in their systems. The difference is that Boeing is looking to implement autonomous aircraft to combat a pilot shortage, while the automotive industry is looking to combat rising fatalities within their industry.

Conclusion

Currently, UASs are very limited in what they can do, due to FAA regulations. Companies such as Amazon, are working to convince the FAA to allow

UASs to operate with less restrictions within the NAS (Amazon, 2015). Risk perception plays a large role in everyday life, as it drives human decisions every day (Slovic, 1987). These perceptions are driven largely by emotions, but not much by the terminology that is used when an entity is releasing something new or controversial (Clothier et al., 2015; Sjöberg, 2007; PyrlikZillig et al., 2018). In the past, new technology has been perceived to be more risky, despite statistical evidence supporting it. This is unlikely to change change with passenger carrying UASs (Becker, 2009; Ortwin & Benighaus, 2012). With self-driving cars becoming a reality, perceptions of these systems could align with those associated with self-piloted aircraft. Currently the perceptions of self-driving cars is a bit controversial and largely relies on a specific type of situation (Hulse et al., 2018; Reinhart, 2018). Whether it be as a passenger of the vehicle, or as a pedestrian near the vehicle, society has different feelings about these technolgies (Hulse et al., 2018). With the airline industry facing a pilot shortage, aircraft manufacturers are looking to implement automation as a fix (Bellamy, 2017). Studies such as Nullmeyer et al. (2007) have shown that it is quite difficult to remove human error from the cause of incidents. This research set out to answer the question: What are the current perceptions of the general public regarding autonomous passenger carrying aircraft?

CHAPTER 3

Methodology

Participants

This survey was disseminated on social media and attained 165 recorded responses. Due to one participant taking the survey nine times, the data was reduced to a total of 157 responses. Of these respondents, the average age was about 40 years old. The majority identified as male with 91 participants followed by those that identified with female at 65 participants. One participant preferred not to disclose their gender identity. The majority of respondents selected white as their ethnicity, with over 84%. Lastly, 63% of participants stated they had some sort of higher education degree, including Associate's, Bachelor's, Master's, and higher. These demographics are described in further detail in chapter four.

Research Materials

A survey was used to collect data to determine the public's current perceptions of autonomous and unmanned aircraft. The survey was developed in Google Forms. This allowed the researcher to access responses from all participants in a generated spreadsheet. The survey was disseminated on the social media platforms of Facebook and LinkedIn.

Prior to beginning the survey, participants were presented with a letter from the researcher stating that the participant would remain anonymous and there was no personal data taken during the survey. The letter also informed the participant that by completing the survey, they provided consent for their responses to be used in the present study. This letter is in Appendix A

In order to identify participants who are active in the aviation industry, the survey included a question to reveal this. By isolating these participants, the researcher was able to distinguish between those with aviation background and those without. This method also reduced the amount of bias that is represented in the data due to worries of aviation industry employees, such as job security implications.

The survey is found in Appendix B. All questions except for one, were based on research described in the literature review. One question type that is asked was inspired by Sjöberg (1982). These questions ask respondents to make an assessment which emotions best represented their feeling about a given technology (Appendix B). The answer choices for these questions were randomized in effort to prevent respondents from subconsciously picking the same answer for different topics.

Data and Analysis

One participant took the survey nine times within the course of one hour, due to responses to all questions, including the freeform short answer, being identical. In order to prevent an issue with results, 8 of these 9 redundant responses were removed from the data. This left a total of 157 responses to the survey that were analyzed. Responses to the individual questions are discussed, followed by the results of statistical analysis.

On questions asking respondents to select emotions that best represented their feeling to a given technology, there was an "Other" option that allowed the respondent to enter their own emotion. Some respondents treated this section as a comment section and did not provide an emotion-based answer. Irrelevant data were removed from the data set for analysis. All comments can be found in Appendix C.

To better analyze the data that was attained from the survey, the Likert scale questions were reduced into three categories depending on what the question was asking. Originally the Likert questions were on a scale from one to five. For example, the questions that asked how comfortable the participant was with a given technology, were recategorized into comfortable, not comfortable, and neutral, as opposed to very comfortable, comfortable, neutral, uncomfortable, and very uncomfortable. For statistical analysis, Neutral was considered as no opinion, and was not considered in the chi-square statistical analysis.

Chi-square analysis was performed on each question to determine what types of correlations exist. This allowed the researcher to find connections between responses to different questions. The results of the analysis run on the data for each question can be found in chapter four.

CHAPTER 4

Results

This chapter lays out the results of the survey. Most questions have an associated bar chart that helps depict which answers were selected the most. Responses to each individual question is discussed first. This is then followed by the results of the statistical analysis that was run on the survey data.

Demographics

The following questions focused on demographics, this includes gender, age, ethnicity, and education level.

Question 1. *What gender do you identify with?*

Out of the 157 response, 65 participants selected female, 91 selected male, and 1 preferred not to answer. This means 41.4% of respondents were female, 57.9% of respondents were male, and 0.7% preferred not to answer.

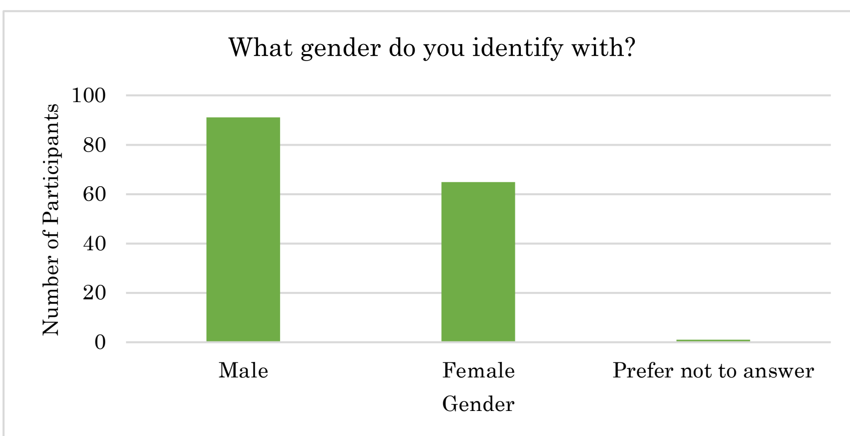

Figure 2. Number of participants that selected male, female, and chose not to answer. N= 157.

Question 2. *How old are you?*

The survey had a large variety of responses with regards to age. The minimum age was 18 years old, and the maximum was 83 years old. The average age of participants was 39.56 years old.

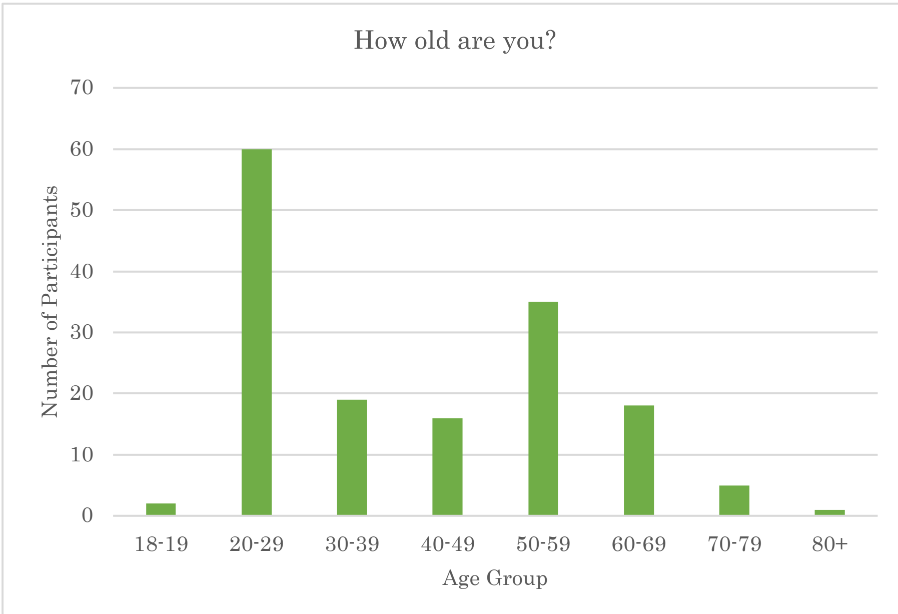

Figure 3. Quantity of participants broken into 10-year age groups. N= 156.

Question 3. *What is your ethnicity?*

The vast majority of respondents were white at 84.1%. The next highest minority was Asian at 8.9%. Hispanics made up 1.9% of participants, while Pacific Islanders made up 1.3%. The remaining 3.8% were made up of African Americans, American Indians, Indians, Mexican and Palestinians, and Native Americans with 1 participant in each category.

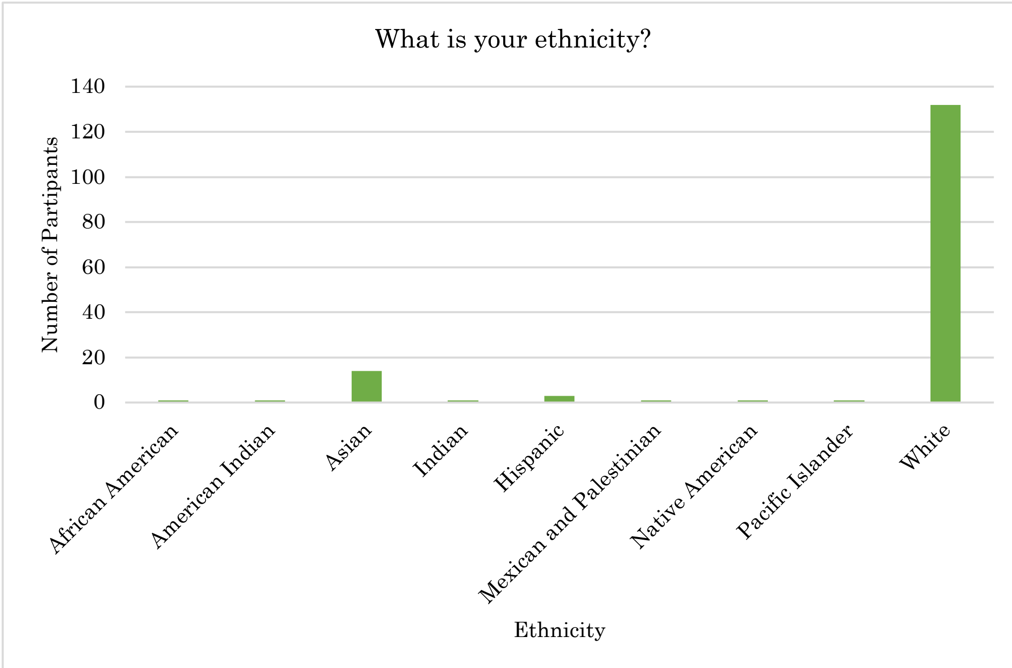

Figure 4. Number of participants that selected each ethnicity. N= 157.

Question 4. *What is your education level?*

The majority of respondents had at least a bachelor's degree with 38.2%. The next highest was those with some college experience at 29.9%. The remaining options of Associate degree, some graduate school, high school graduate, Master's degree, other advanced degree beyond a Master's, and Ph.D., law, or medical degree were all below 10%. The data for this question is represented in Figure 5.

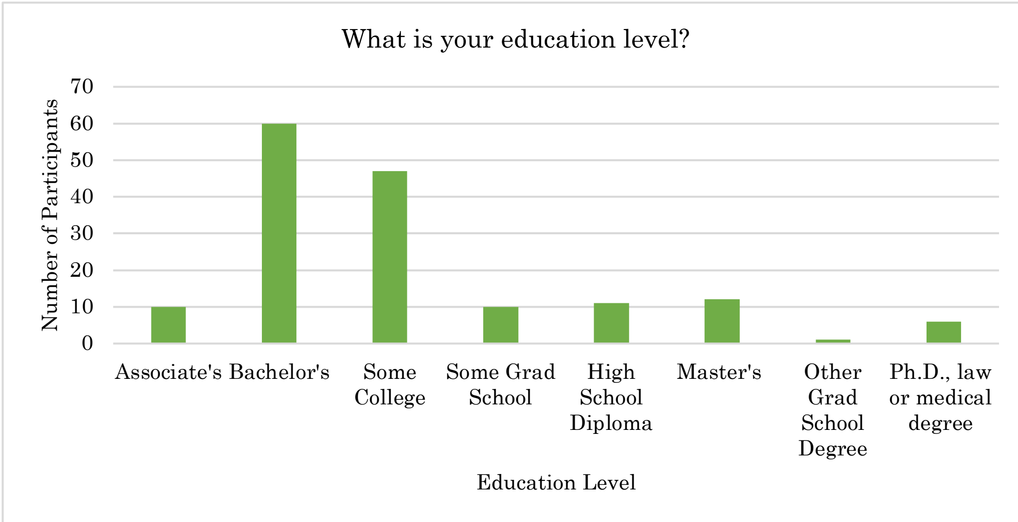

Figure 5. Educational level of respondents. N= 157.

Aviation Experience

These questions focused on determining whether participants had aviation experience, and if so, what type. This included determining how often they travel via airplane, their familiarity with UAS, and other similar questions.

Question 5. *How often do you fly as a passenger on commercial airliners?*

Figure 6 below shows a bar chart for how often respondents fly on commercial airliners. The largest percentage, 25.5%, came from those that fly once every 6 months. 24.8% said they fly once per quarter. The next highest majority was 11.5% flying once per month. This followed by 3.8% that fly once per week, and 4.5% fly more than once per week. This equates to 70.1% flying 2 times per year or more. The remaining 29.9% fly less than 2 times per year or have never flown on a commercial airliner before.

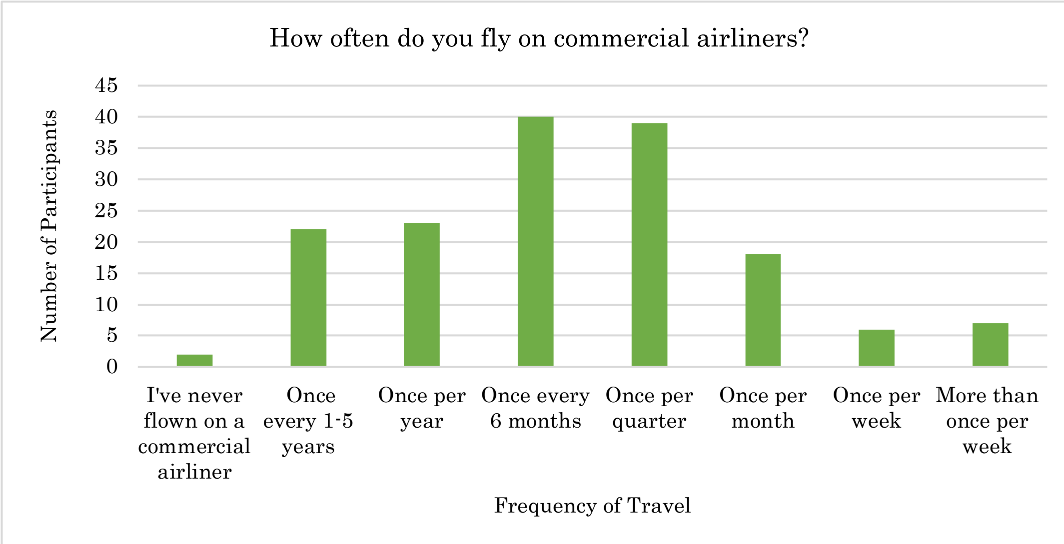

Figure 6. Travel frequency of respondents. N= 157.

Question 6. *Which of these applies to you? (Aviation industry background)*

Of the 157 survey participants, 98 answered they have some aviation background. This means 63% of respondents have at least some aviation background, including simply following the industry. The majority who claimed they had aviation background, are employed in the aviation industry. Very few respondents, 4, were Part 107 certified to operate a drone for commercial purposes. Another 16 respondents said they operate hand flown drones. Table 1 depicts the how participants responded to this question.

Table 1
Question 6

	Employed in aviation industry	General Aviation Pilot	Operator of Hand Flown Drones	Part 107 Certified	Not Employed, Avidly Follows	Student in Aviation Program
Quantity (%)	58 (.37)	26 (.17)	16 (.10)	4 (.03)	34 (.22)	7 (.04)

Note. Quantity is out of 157 respondents. This question received 98 responses.

Question 7. *How familiar are you with Unmanned Aerial Systems?*

Survey participants were asked to rank on a scale from 1 to 5 how familiar they were with UAS. All 157 respondents answered this question with, 60 (38.2%) respondents indicated they were very unfamiliar, 16 (10.2%) indicated they were unfamiliar with these systems. 39 (24.8%) ranked their familiarity at 3 out of 5. A rank of 4 out of 5 was selected by 19 (12.1%), with the remaining 23 (14.7%) selecting very familiar. When these responses were recategorized into familiar or unfamiliar, 76 (48.4%) were unfamiliar, and 42 (26.8%) were familiar, therefore majority of respondents were unfamiliar with UAS.

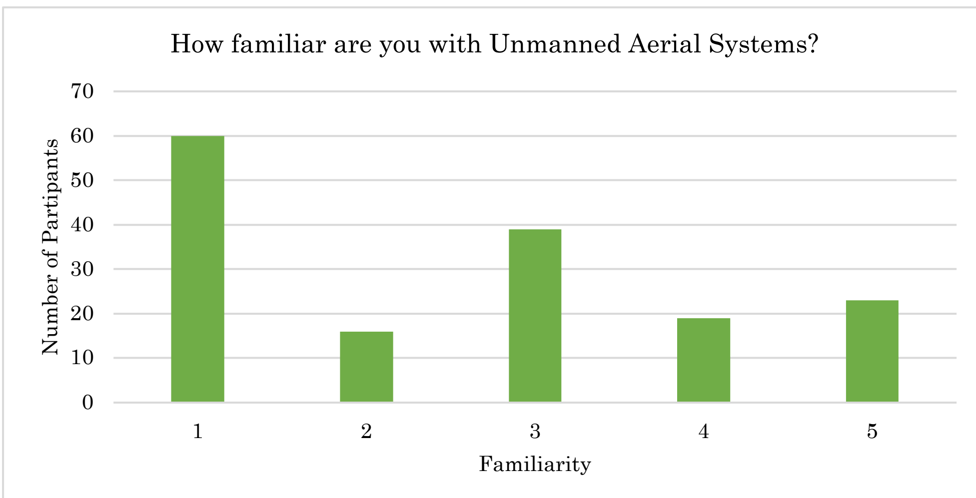

Figure 7. Number of participants that selected each familiarity level. N= 157.

Comfort and Emotion Questions

Questions 8 through 17 asked participants to disclose their comfort level and emotional feeling about various technologies. After each comfort level question, participants were asked to select which emotions best represented their feeling about the given technology.

Question 8. *How comfortable are you with self-driving cars?*

Participants were asked how comfortable they were with self-driving cars. Figure 8 shows the frequency based on comfort level. The total number of respondents to this question were 157.

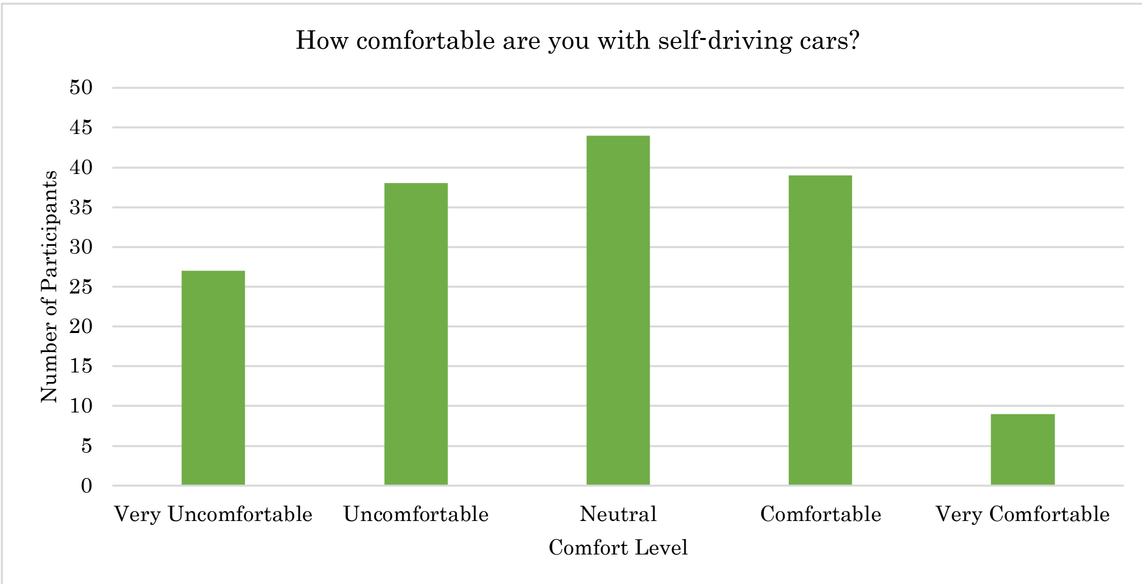

Figure 8. Number of participants for each comfort level with regards to self-driving cars. N= 157.

For statistical analysis, the responses to this question were recategorized into "comfortable" and "uncomfortable," responses of "neutral" were declared as no opinion. When data was grouped into "Comfortable" and "Uncomfortable" for the analysis, the result was 65 uncomfortable, and 48 were comfortable.

Question 9. *Looking at the emotions below, make a selection of all the emotions that best represents your feeling about self-driving cars.*

Figure 9 below shows which emotions respondents felt best represented how they felt about self-driving cars. The top three answers were "Interest", "Optimism", and "Worry". "Interest" was selected 99 times, which is 63.1%, followed by

“Optimism” which was selected 84 times, or by 53.5% of respondents. Lastly, worry was selected 74 times, which is 47.1%.

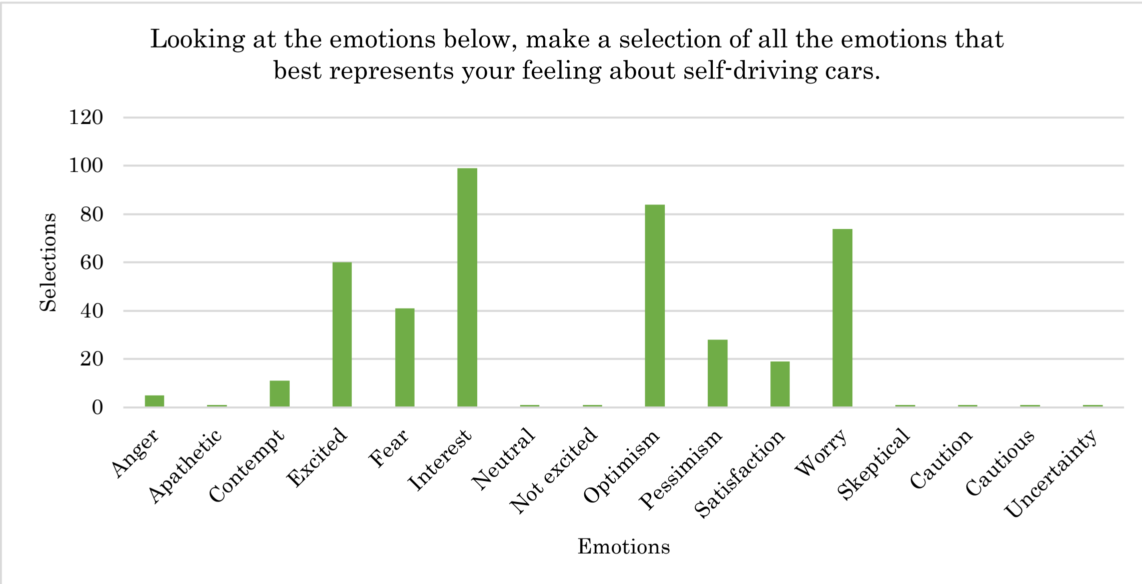

Figure 9. Number of times each emotion was selected. N= 157.

Question 10. *How comfortable are you with drone delivery services?*

Participants were asked how comfortable they were with drone delivery services. Figure 10 shows the number of participants in a bar chart based on comfort level. The total number of respondents to this question were 157.

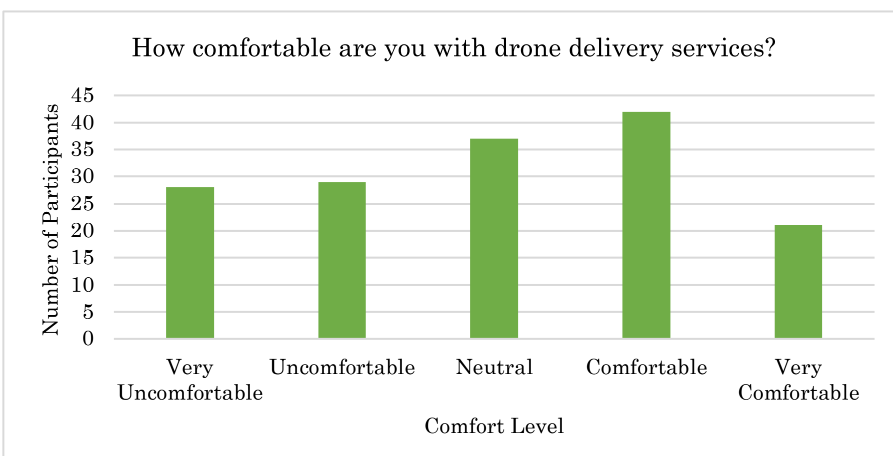

Figure 10. Number of participants for each comfort level with regards to drone services. N=157.

As stated before, these results were reduced to “Comfortable” and “Uncomfortable” in order to analyze those with opinions. 57 respondents were uncomfortable with drone delivery services, while 63 respondents felt comfortable with drone delivery services.

Question 11. *Looking at the emotions below, make a selection of all the emotions that best represents your feeling about drone delivery services.*

The top three answers were “Interest”, “Optimism”, and “Worry”. This question shares the top three answers with question 9, about self-driving cars. “Interest” was selected 98 times, which is 62.4%, followed by “Optimism” which was selected 68 times, or 43.3% of respondents, and 66 responding with “Worry” at 42.0%. This data is displayed in Figure 11.

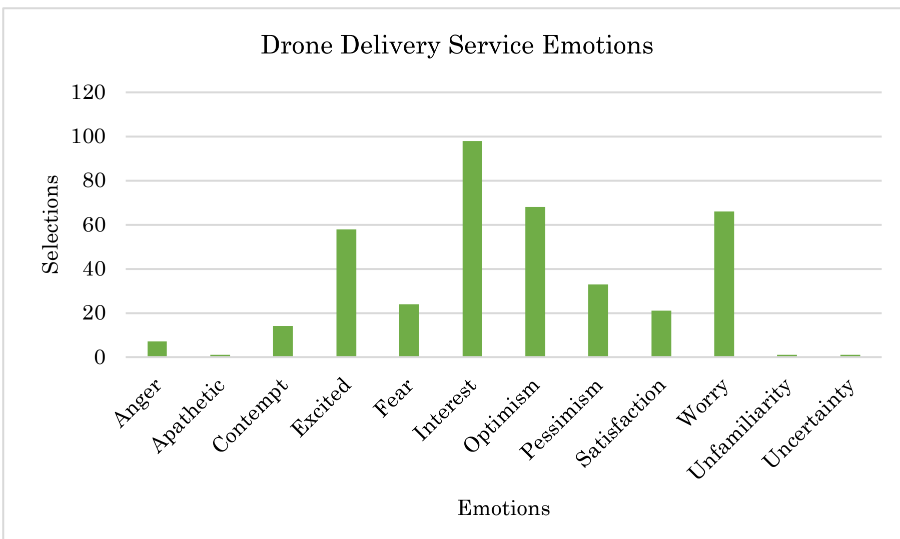

Figure 11. Number of times each emotion was selected. N= 157.

Question 12. *How comfortable are you with the current state of safety in air travel?*

Question 12 asked participants their current comfort level with the current state of safety in commercial air travel. The majority of respondents answered they were either comfortable, or very comfortable with the current state of safety in air travel. Only 3 respondents felt uncomfortable in any way about the current state of safety in air travel. This data is displayed in Figure 8. When the responses to this question were reduced to “Uncomfortable” and “Comfortable” for statistical analysis, “Comfortable” was the majority with 133 (84.7%), with only 3 selecting “Uncomfortable” with 1.9%.

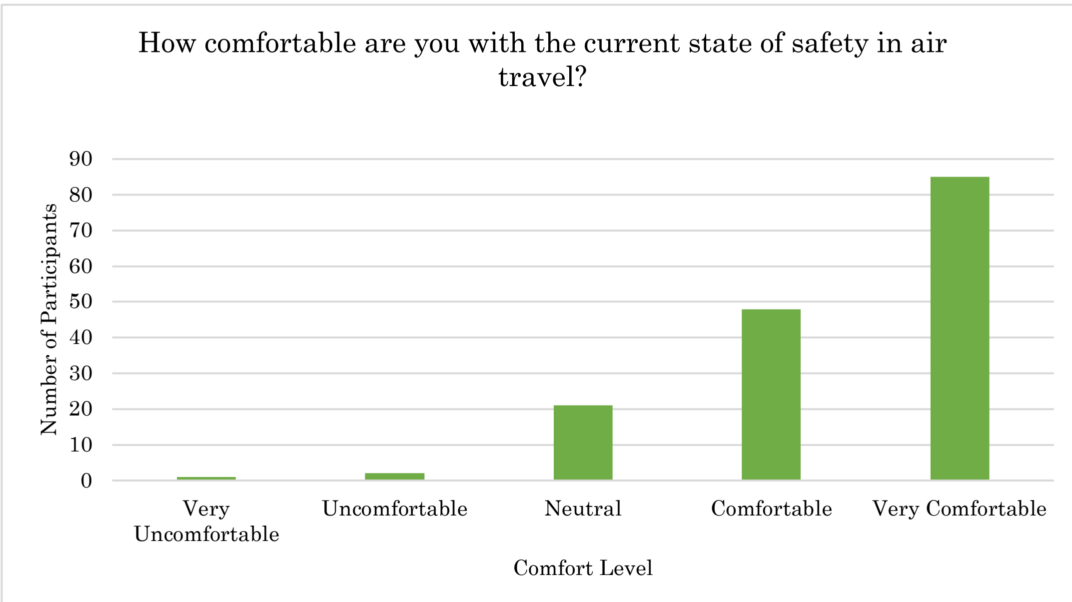

Figure 12. Quantity for participant’s comfort level with regards to the current state of safety in air travel. N=157.

Question 13. *Looking at the emotions below, make a selection of all the emotions that best represents your feeling about the current state of safety in air travel.*

The top three answers to this question were “Satisfaction”, “Optimism”, and “Interest”. That said, the overwhelming answer was “Satisfaction” with 79.0%, or 124, of respondents selecting. This was followed by “Optimism” with 63 (40.1%) participants, and “Interest” with 44 (28.0%). This data is shown in Figure 13.

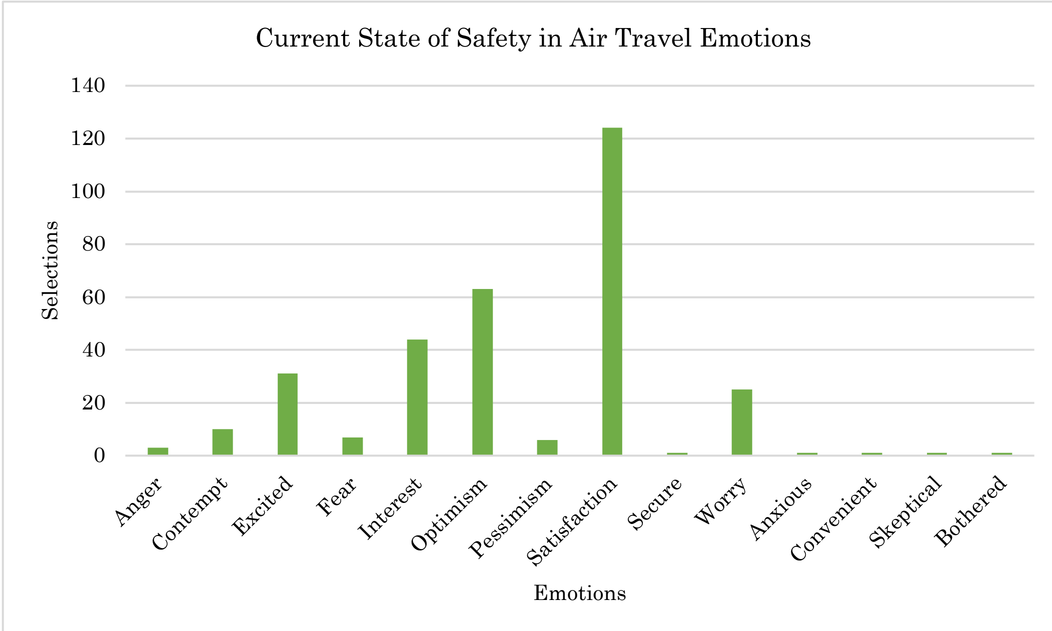

Figure 13. Number of times each emotion was selected. N= 157.

Question 14. *How comfortable would you be as a passenger on an airline flight that had one pilot as opposed to two?*

Participants were asked how comfortable they would be if aircraft were to be flown by one pilot as opposed to two. Forty-four respondents selected uncomfortable, with another 32 selecting very uncomfortable. Figure 14 shows the number of participants that selected each answer choice to question 14.

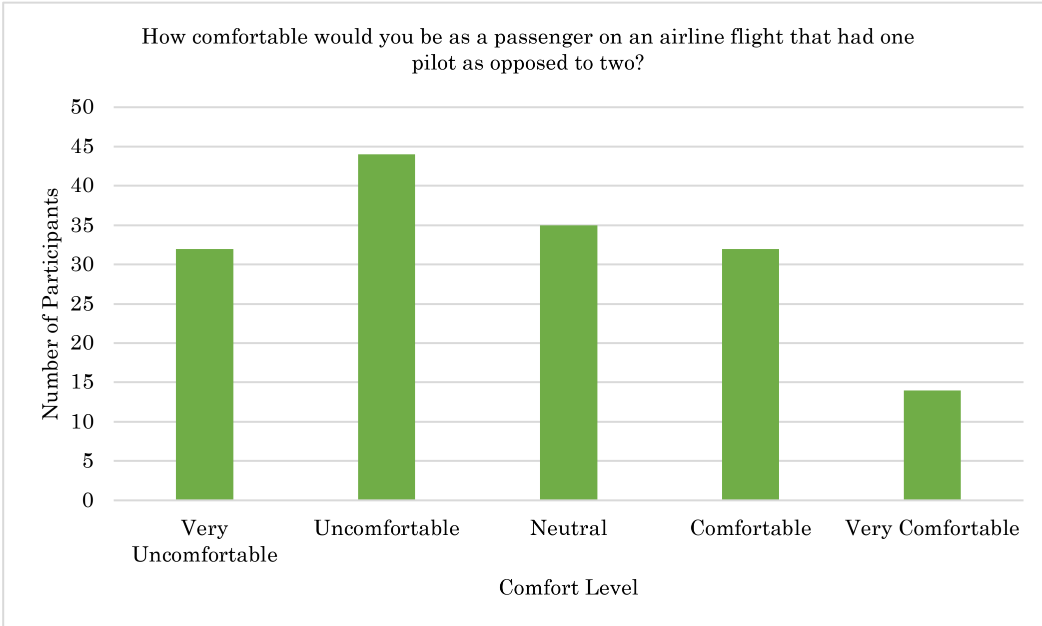

Figure 14. Number of participants for each comfort level with regards to a one pilot operation as opposed to the current 2. N= 157.

Question 15. *Looking at the emotions below, make a selection of all the emotions that best represents your feeling about being a passenger on an airliner with only one pilot instead of two.*

Figure 15 shows which emotions respondents felt best represented how they felt about being a passenger on an aircraft that was flown by one pilot, as opposed to two. The top two answers were "Worry" and "Fear". That said, respondents did show some interest with 39 respondents selecting "Interest". This was behind "Worry" with 85 (54.1%) participants, and "Fear" with 55 (35.0%).

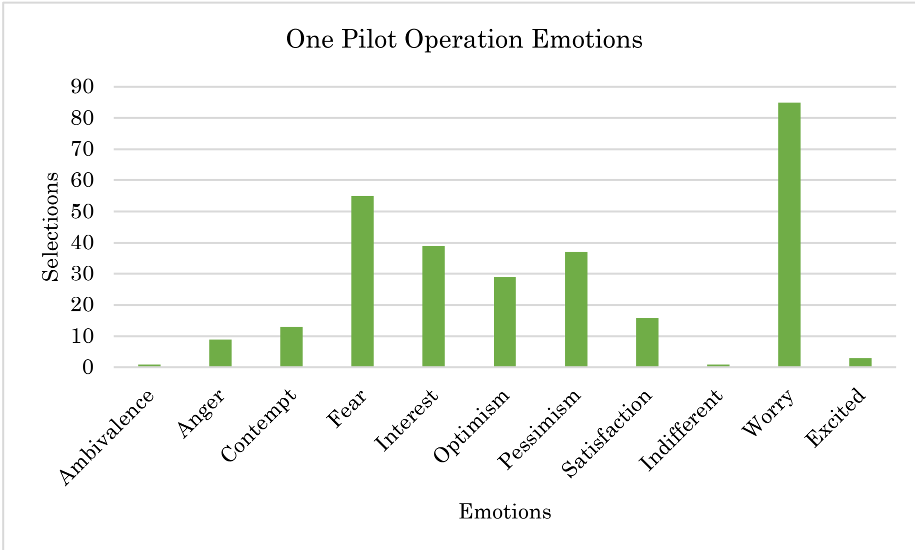

Figure 15. Number of times each emotion was selected. N= 157.

Question 16. *How comfortable would you be if airline flights had no pilot on board and operated fully autonomously?*

This question asked respondents how comfortable they were with the idea of being a passenger on a fully autonomous aircraft. The majority of respondents, 89, selected "Very Uncomfortable" with the idea of this technology. This is 56.7% of respondents. The next most selected answer was "Uncomfortable" with 21 (13.4%) respondents. This is a total of 70.1% being uncomfortable with the idea of being a passenger on a pilotless aircraft. Participants were particularly more uncomfortable with this than with a single pilot operation. One participant stated as a comment, "I would not get on an airplane without at least one pilot as a backup" (Appendix C). It was quite common for respondents to mention their lack of comfort was rooted from a machine having control. "I generally don't trust anything operated completely by machinery without oversight from a human being" (Appendix C). The results of this question are depicted below in Figure 16.

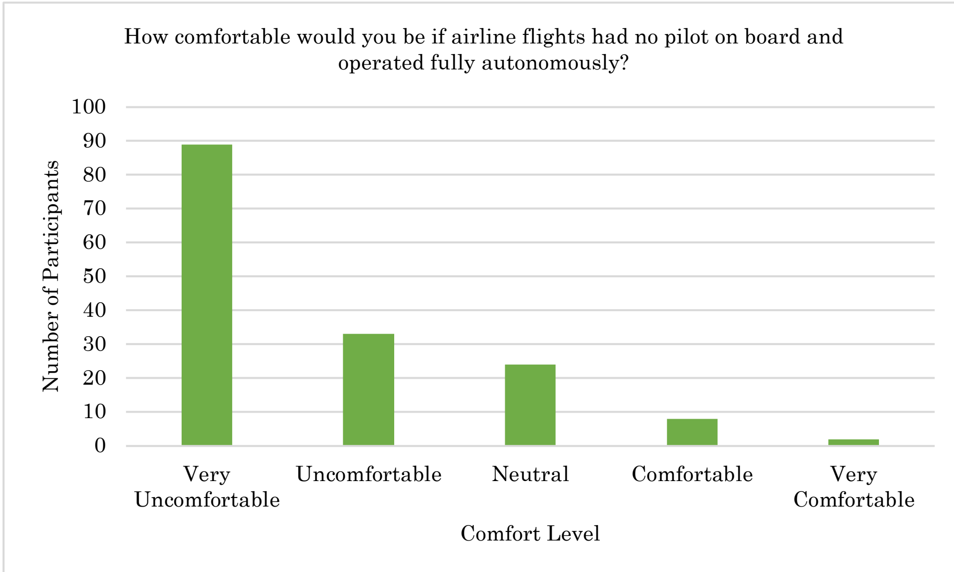

Figure 16. Number of participants for each comfort level with regards to fully autonomous aircraft. N= 157.

Question 17. *Looking at the emotions below, make a selection of all the emotions that best represents your feeling about being a passenger on a fully autonomous airline flight?*

The top two answers were "Worry" and "Fear" with 110 and 103. This shares the same top two emotions to responses for question 15 regarding a one pilot operation. The next highest was "Pessimism" with 62 responses.

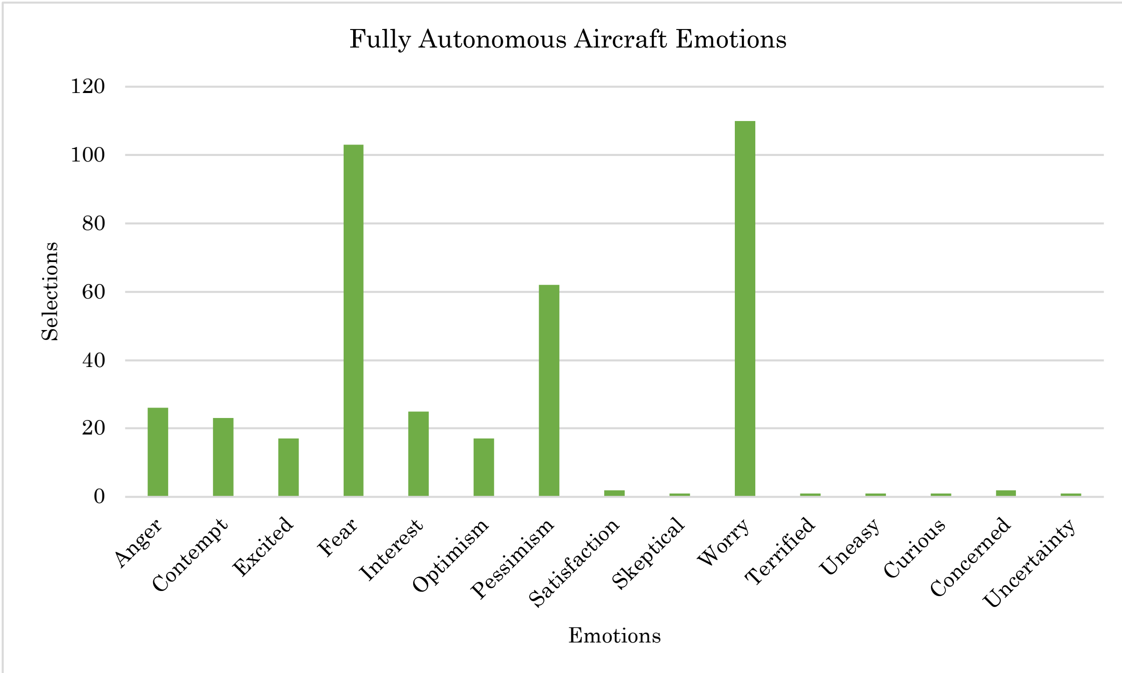

Figure 17. Number of times each emotion was selected. N= 157.

Future Perception

Question 18. *How far into the future do you see pilotless commercial aircraft carrying cargo?*

Question 18 asked respondents to choose a timeframe for how long they believe it will be until autonomous cargo carrying aircraft will be operating in the NAS. Most participants selected 5-10 years with 42 responses. The next highest was 3-5 years with 39 responses. This means more than 50% of respondents believe this technology is coming in the next decade. All responses and their quantity are depicted in Figure 18.

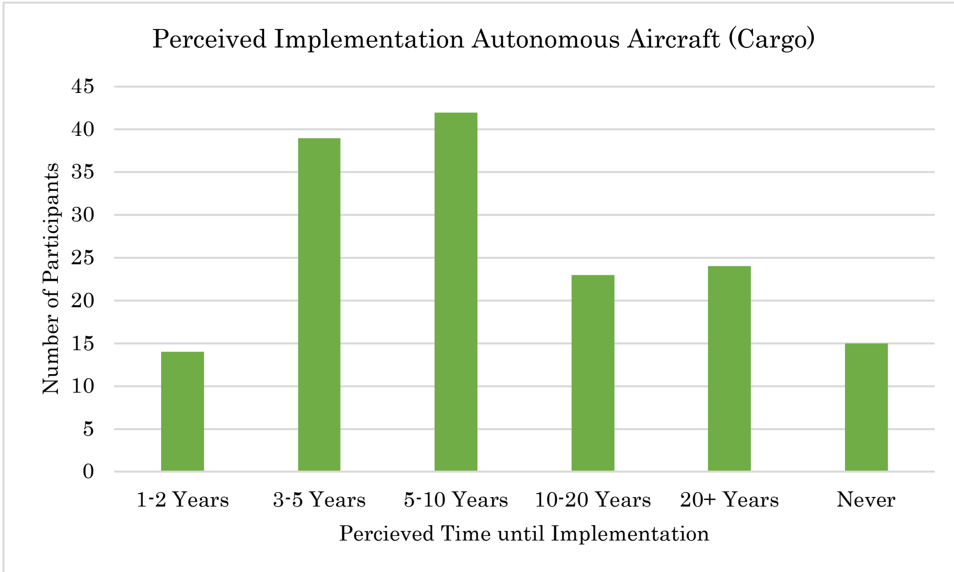

Figure 18. Perceived amount of years, including "Never" until implantation of cargo carrying autonomous aircraft. N= 157.

Question 19. *How far into the future do you see pilotless commercial aircraft carrying passengers?*

The final question asked for respondents to choose a timeframe of how long they believe it will be until autonomous passenger carrying aircraft come to fruition. The highest selected option was "Never" with 42 respondents. Figure 19 shows that 1 respondent selected this technology will be implemented in one to two years, 12 responded three to five years, 26 selected five to ten years, 36 responded with 10 to 20 years, and 40 with 20 or more years.

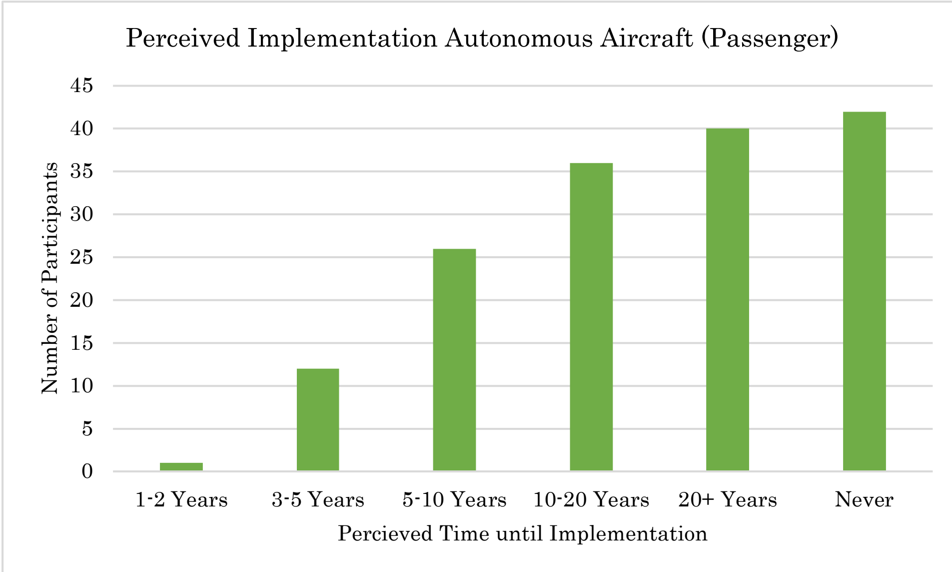

Figure 19. Perceived amount of years, including "Never" until implantation of passenger carrying autonomous aircraft. N= 157.

Analysis

Demographic analysis. Due to a lack of age variance between age groups, age was not considered as part of the analysis. Also, due to the lack of variance in ethnicities, this question was not considered in the statistical analysis. The chi-square analysis that compared the data in question one (gender identity) and question four (education level) to the data from the comfort level and aviation background questions was found to be insignificant. This is shown in Table 8 on page 42.

Aviation experience. The aviation experience questions were also compared to the comfort level questions utilizing a chi-square analysis. The only significant comparison found was between those that stated they were general aviation pilots, and their comfort level with a single pilot operation (chi-square, df=2, Value=19.448, p=5.982e-05). This is further discussed in the following section. The remaining comparisons were found to be insignificant. This can be seen in Table 9 on page 43.

Comfort Level. The comfort level questions were compared amongst themselves using a chi-square analysis. There were numerous comparisons that were found to be significant; these are described in detail below.

There was statistical significance when comparing the comfort level of self-driving cars, and drone delivery services. (chi-square, df=1, Value=34.056, p=5.356e-09). Respondents typically responded with the same comfort level on both self-driving cars, and drone delivery services. This is shown in Table 2.

Table 2

Question 8 and 10

	#Uncomfortable (%) Drone Delivery	#Comfortable (%) Drone Delivery
#Uncomfortable (%) Self-Driving Car	39 (.24)	14 (.08)
#Comfortable (%) Self-Driving Car	3 (.02)	33 (.21)

Note. N= 157. 89 answered with an opinion on both questions.

Question 14's chi-square analysis was found to be significant when compared to those that are general aviation pilots. Looking at Table 3 below, those who were general aviation pilots were more likely to select uncomfortable with a one pilot operation (chi-square, df=2, Value=19.448, p=5.982e-05).

Table 3

Question 6 and 14

	#Non GA Pilot (%)	#GA Pilot (%)
#Uncomfortable (%) One Pilot	57 (.36)	19 (.12)
#Comfortable (%) One Pilot	43 (.27)	3 (.02)

Note. N= 157. 122 answered with an opinion on both questions.

Question 14's chi-square analysis was also found to be statistically significant when compared to the responses received for question 8, regarding self-driving cars.

Those that selected uncomfortable when asked about self-driving cars, were more likely to continue that feeling with a single pilot operation. Those that felt comfortable with self-driving cars, were also comfortable with a single pilot operation as well (chi-square, df=1, Value=14.557, p=1.00e-03). These results can be seen in Table 4.

Table 4

Question 8 and 14

	#Uncomfortable (%) Self-Driving Car	#Comfortable (%) Self-Driving Car
#Uncomfortable (%) One Pilot	36 (.23)	13 (.08)
#Comfortable (%) OnePilot	11 (.07)	26 (.17)

Note. N= 157. 86 answered with an opinion on both questions.

Question 14's chi-square analysis also found statistical significance when compared to the responses for question 11, which asked respondents their comfort level with drone delivery services. Much like the comparison with question 8, those that were uncomfortable with a one pilot operation, were uncomfortable with drone delivery services. Also, those that selected they were comfortable with drone delivery services, were more likely to be comfortable with a single pilot operation on commercial aircraft (chi-square, df=1, Value=25.416, p=4.621e-07). These results are shown below in Table 5 One respondent felt that autonomous technology was actually safer than one pilot, "…I feel it would be safer to be in an autonomous aircraft rather than a commercial flight with only one pilot and no other human or fully autonomous backup for human error" (Appendix C).

Table 5

Question 10 and 14

	#Uncomfortable (%) Drone Delivery	#Comfortable (%) Drone Delivery
#Uncomfortable (%) One Pilot	41 (.26)	18 (.11)
#Comfortable (%) One Pilot	6 (.04)	33 (.21)

Note. N= 157. 98 answered with an opinion on both questions.

For question 16, the results were reduced to 122 uncomfortable, and 10 comfortable. Question 16 found statistical significance when compared to the answers from question 11 which asked participants their comfort with self-driving cars. The analysis found those that selected they were uncomfortable with self-driving cars were more likely to be uncomfortable with pilotless passenger aircraft (chi-square, df=1, Value=12.809, p=2.0e-4). This is shown in Table 6. The minority that selected comfortable with both of these technologies was not highly represented in the comments, but one air traffic controller stated, “I have been in the air traffic control business for 34 years and have seen a huge amount of change in that time. UAS and self-driving cars are inevitable” (Appendix C).

Table 6

Question 11 and 16

	#Uncomfortable (%) Self-Driving Car	#Comfortable (%) Self-Driving Car
#Uncomfortable (%) Autonomous Aircraft	60 (.38)	26 (.17)
#Comfortable (%) Autonomous Aircraft	1 (.06)	8 (.05)

Note. N= 157. 95 answered with an opinion on both questions.

Lastly, question 16 also had statistical significance when compared to the question that asked respondents for how comfortable they were with a one pilot operation. Respondents were found to be more likely to respond uncomfortable with autonomous aircraft if they were also uncomfortable with a one pilot operation (chi-square, df=1, Value=15.607, p=.7.80e-05). Looking at Table 7, it is clear that the majority of respondents were uncomfortable with both a one pilot operation and a no pilot operation.

Other than the comparisons that were discussed above, the remaining comparisons were found to be insignificant when using the chi-square analysis. These results, both significant and insignificant can be seen in Table 10 on page 44.

Table 7

Question 14 and 16

	#Uncomfortable (%) One Pilot	#Comfortable (%) One Pilot
#Uncomfortable (%) Autonomous Aircraft	72 (.46)	25 (.16)
#Comfortable (%) Autonomous Aircraft	0 (.00)	8 (.05)

Note. N= 157. 105 answered with an opinion on both questions.

Table 8

Significant Demographic Results

	Demographic	
	Gender	Education
Demographic		
Gender	-	
Education		-
Aviation Background		
Travel Frequency		
UAS Familiarity		
Employed Aviation		
Follows Industry		
GA Pilot		
Drone Operator		
Part 107 Cert.		
Aviation College		
Comfort Level		
Self-Driving Car		
Drone Delivery		
Current State		
One Pilot		
No Pilot		

Note. No results recorded when p>.05. Dash indicates comparison with same variable.

Table 9

Significant Aviation Background Results

	Aviation Experience							
	Travel Freq.	UAS Fam.	Employed Aviation	Follows Ind.	GA Pilot	Drone Oper.	107 Cer	College
Demographic								
Gender								
Education								
Aviation Exper.								
Travel Freq.	-							
UAS Familiarity		-						
Employed Aviation			-					
Follows Industry				-				
GA Pilot					-			
Drone Operator						-		
Part 107 Cert.							-	
College								-
Comfort Level								
S. Driving								
Drone Delivery								
Current State								
One Pilot					5.98 E-05			
No Pilot								

Note. No results recorded when p>.05. Dash indicates comparison with same variable.

Table 10

Significant Comfort Level Results

	Comfort Level				
	Self-Driving Car	Drone Delivery	Current State	One Pilot	No Pilot
Demographic					
Gender					
Education					
Aviation Background					
Travel Frequency					
UAS Familiarity					
Employed Aviation					
Follows Industry					
GA Pilot				5.98E-05	
Drone Operator					
Part 107 Cert.					
Aviation College					
Comfort Level					
Self-Driving Car	-	5.36E-09		1.00E-03	2.00E-04
Drone Delivery	5.36E-09	-		4.62E-07	
Current State			-		
One Pilot	1.00E-03	4.62E-07		-	7.80E-05
No Pilot	2.00E-04			7.80E-05	-

Note. No results recorded when p>.05. Dash indicates comparison with same variable.

CHAPTER 5

Discussion

The purpose of this study was to determine the public perceptions associated with automation in aircraft. A survey focused on comfort levels with various types of automated technology was disseminated to participants. The study found significant results, using chi-square analysis. Overall when it comes to fully autonomous aircraft, the data shows that society is not currently comfortable with the idea.

Significant Results

Significant results were found when comparing the responses of general aviation pilots to those who are not general aviation pilots, and their comfort level with a one pilot operation. Overall, the majority of respondents selected they were uncomfortable with a single pilot operation, but those who are general aviation pilots were more likely to be uncomfortable with a single pilot air carrier operation than those who are not general aviation pilots. This is likely because most general aviation pilots operate smaller aircraft with one pilot as opposed to two and understand the workload that is involved with operating an aircraft as the single pilot operating the aircraft.

The study also found statistical significance between the participant's responses to comfort level questions regarding self-driving cars and drone delivery services. The results showed that the comfort level was likely to be the same between the two technologies, whether it be comfortable or uncomfortable. For instance, when a participant selected that they were comfortable with self-driving cars they were likely to also select comfortable with drone delivery services. This was also the case with those who selected uncomfortable for both self-driving cars and drone delivery services. This held true when comparing comfort levels associated with self-driving cars and one pilot operations; as well as drone delivery services and one pilot operations. The data shows that those who are uncomfortable with automation tend to stick with being uncomfortable across self-driving cars, drone delivery services, and one pilot operations. It also shows that those who are comfortable with automation tend to remain comfortable with self-driving cars, drone delivery services. No significance could be found to explain what determined why someone was comfortable or uncomfortable with these technologies.

The question regarding participants comfort level with fully autonomous aircraft showed a different response. The results show that the majority of participants were uncomfortable with fully autonomous aircraft. There was statistical significance found when comparing those that answered uncomfortable for self-driving cars and fully autonomous aircraft. Those that were uncomfortable with self-driving cars were more likely to be uncomfortable with self-flying aircraft. This was also true when comparing responses for fully autonomous aircraft and single pilot operations.

These findings show that overall when people have a stance on automation, they tend to hold that belief across multiple technologies. This does not hold true when asked about fully autonomous aircraft. This technology is not perceived with a positive connotation. The emotions associated with this technology had a largely negative connotation, which is well reflected in their comfort levels. Participants overall selected that they were very uncomfortable with a single pilot operation.

Those that selected this were also more likely to select very uncomfortable with fully autonomous aircraft.

Limitations and Future Studies

This survey was disseminated through the researcher's social media accounts. This led to a younger age group having the majority of all age groups as opposed to a more even distribution of age groups. It is recommended that future studies work to get the survey disseminated through different media to acquire a more balanced spread amongst age groups.

The demographic based questions did not lead to any statistical findings. The researcher believes that future research should work to find different demographics than what was used in the current study. This includes asking participants to disclose different information in order to find underlying reasons for how answers are chosen.

Though this study did have significant findings, future studies should focus on digging deeper into where the perceptions shown in this study come from. The present study exposed the current perceptions of autonomous cars and aircraft, along with the emotions associated with these technologies. Future studies should search for what is behind their perceived risk.

Future studies should also investigate other demographic based questions. One demographic that was not covered in the present study but could be covered in future research is household income. This could be used to see if there is correlation between those with a higher income and their perceptions with these types of technologies.

Implications

The results showed that the majority of respondents are comfortable with the use of self-driving cars, drone delivery services and the current state of safety in air travel. With other items such as a one pilot operation, and a fully autonomous aircraft, this was not the case. With the majority of participants being comfortable with the current state of safety in air travel and uncomfortable with the idea of fully autonomous aircraft, it can be seen that the main reason society is not comfortable could be because society does not want change to the status quo. Since the current state of air travel is satisfying society, there is strong cause for the unknown to be a frightening and worrisome endeavor.

Though the majority of respondents indicated that they were not comfortable with technologies such as self-driving cars, the comfort level was more torn than that of one pilot operations and fully autonomous aircraft. This could be attributed to the idea that participants are uncomfortable with the unknown. Self-driving cars are on the road today, and are rapidly rising in use, making it more known to members of society. This could explain why the comfort level with self-driving cars was more torn than the technologies that have yet to be largely presented.

This trend continues with drone delivery, where the majority of respondents were comfortable with the technology. This has also been largely advertised by amazon, despite not being released in the US. This could indicate that when a company is transparent about their plans, and show the public their process, the public is going to perceive your technology in a more positive light.

With companies like Boeing looking to implement new automated technology in aircraft to counteract a pilot shortage, being transparent is important. Bellamy

(2017) stated that Boeing announced this technology that they will be working on at the Paris Air Show. Though this is slightly transparent, it is to a more niche market than the general public. It is recommended, moving forward, that Boeing keep the public up to date with how this testing is going, and what the timeline is for this type of technology.

Conclusion

The present study revealed current perceptions of autonomy in various technologies. The main goal was to show current perceptions associated with fully autonomous aircraft. It was shown that society is not comfortable with boarding an aircraft with less than two pilots on board; this includes an aircraft that is operating fully autonomously. Participants disclosed their hesitation for this technology in the comment section of the survey (Appendix C).

Though it appears more people are becoming comfortable with self-driving cars based on this study, it appears that even those who are comfortable with this technology are not comfortable with fully autonomous aircraft. With an overwhelming response of uncomfortable feelings toward autonomy in aircraft, it is important for aircraft manufacturers and air carriers looking to implement this technology in the future, distant or near, to take the public perception of these systems into consideration.

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APPENDIX A

SURVEY LETTER

Dear Participant,

I am a graduate student under the direction of Professor Mary Niemczyk in the Department of Aviation at Arizona State University. I am conducting a research study to examine the current perceptions of passenger carrying, pilotless aircraft. The objective of this study is to expose these perceptions, and the emotions that are associated with this technology.

I am inviting your participation, which will involve answering a short 5-minute survey that will ask various questions about air travel. You have the right not to answer any question, and to stop participation at any time. Completing the online survey will be considered your consent to participate.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. There will be no compensation for the time spent on this survey. You must also be 18 years or older to participate in this survey.

Although there is no benefit to you directly, possible benefits of your participation are that the results of this study will help companies, that may be looking to implement new technology, understand the current public perception of certain air travel technologies. There are no foreseeable risks or discomforts to your participation.

This survey will not ask you for any personal information other than basic demographic questions such as your age, sex, and ethnicity. Your name, nor your IP address will be recorded. Your responses will be anonymous. The results of this study may be used in reports, presentations, or publications but your name will not be used.

If you have any questions concerning the research study, please contact the research team at: You may also contact the research team at Mary.Niemczyk@asu.edu (Primary Investigator) or mwollert@asu.edu (Co- Investigator). If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788. Please let me know if you wish to be part of the study.

Thank you for your participation,
Matthew Wollert

APPENDIX B

SURVEY QUESTIONS

Public Perception of Autonomous Aircraft

What gender do you identify with? *

Mark only one oval.

- Male
- Female
- Prefer not to answer

How old are you? *

What is your ethnicity? *

Mark only one oval.

- African American
- Asian
- Hispanic
- Pacific Islander
- White
- Other:

What is your educational level? *

Mark only one oval.

- Not a high school graduate
- High school graduate
- Completed some college
- Associate degree
- Bachelor's degree
- Completed some postgraduate
- Master's degree
- Ph.D., law or medical degree
- Other advanced degree beyond a Master's degree

How often do you fly as a passenger on commercial airliners? *

Mark only one oval.

- I've never flown on a commercial airliner
- Once every 1-5 years
- Once per year
- Once every 6 months
- Once per quarter
- Once per month
- Once per week
- More than once per week

Which of these applies to you (check all that apply, check none if none apply):
Check all that apply.

- I am employed in the aviation industry
- I am general aviation pilot
- I operated hand flown drones
- I hold a Part 107 Remote Pilot Certificate
- I am not employed in the aviation industry, but avidly follow the industry
- I am a student in an aviation education program (i.e. College)

How familiar are you with Unmanned Aerial Systems?
Mark only one oval.

	1	2	3	4	5	
Very Unfamiliar						Very Familiar

How comfortable are you with SELF-DRIVING CARS? (i.e. Tesla, Uber, and Waymo) *

Mark only one oval.

	1	2	3	4	5	
Not at all comfortable						Very comfortable

Looking at the emotions below, make a selection of all the emotions that best represents your feeling about SELF-DRIVING CARS: *

Check all that apply.

- Anger
- Fear
- Worry
- Optimism
- Pessimism
- Satisfaction
- Contempt

- Excited
- Interest
- Other:

How comfortable are you with an unmanned aerial system (UAS), otherwise known as a drone delivering your package? (i.e. Amazon Prime Air) *

Mark only one oval.

	1	2	3	4	5	
Not at all comfortable						Very comfortable

Looking at the emotions below, make a selection of all the emotions that best represents your feeling about DRONE DELIVERY SERVICES: *

Check all that apply.

- Contempt
- Optimism
- Interest
- Excited
- Pessimism
- Worry
- Satisfaction
- Anger
- Fear
- Other:

How comfortable are you with THE CURRENT STATE OF SAFETY IN AIR TRAVEL? *

Mark only one oval.

	1	2	3	4	5	
Not at all comfortable						Very comfortable

Looking at the emotions below, make a selection of all the emotions that best represents your feeling about THE CURRENT STATE OF SAFETY IN AIR TRAVEL: *

Check all that apply.

- Satisfaction
- Contempt
- Worry
- Interest
- Pessimism
- Anger
- Fear
- Optimism
- Excited
- Other:

How comfortable would you be as a passenger on an airline flight that had ONE pilot as opposed to TWO? *
Mark only one oval.

	1	2	3	4	5	
Not at all comfortable						Very comfortable

Looking at the emotions below, make a selection of all the emotions that best represents your feeling about BEING A PASSENGER ON AN AIRLINER WITH ONLY ONE PILOT INSTEAD OF TWO: *

Check all that apply.

- Excited
- Fear
- Pessimism
- Worry
- Optimism
- Anger
- Interest
- Contempt
- Satisfaction
- Other:

How comfortable would you be if airline flights had no pilot on board and operated FULLY AUTONOMOUSLY? *
Mark only one oval.

1 2 3 4 5

Not at all comfortable | Very comfortable

Looking at the emotions below, make a selection of all the emotions that best represents your feeling about BEING A PASSENGER ON A FULLY AUTONOMOUS AIRLINE FLIGHT? *

Check all that apply.

- Anger
- Interest
- Satisfaction
- Optimism
- Excited
- Worry
- Fear
- Pessimism
- Contempt
- Other:

How far into the future do you see pilotless commercial aircraft carrying CARGO? *
Mark only one oval.

- 1-2 Years
- 3-5 Years
- 5-10 Years
- 10-20 Years
- 20 Years or more
- Never

How far into the future do you see pilotless commercial aircraft carrying PASSENGERS? *
Mark only one oval.

- 1-2 Years
- 3-5 Years
- 5-10 Years
- 10-20 Years
- 20 Years or more

- Never

Please provide any additional comments below:

APPENDIX C

SURVEY PARTICIPANTS COMMENTS

1) “Interesting survey”

2) “My tummy hurts”

3) “The world of aviation is too dynamic for aircraft to carry people or property for hire.”

4) “I don't understand pilot less planes and driver less cars when we should he providing jobs for pilots and taxi/Uber/Lyft drivers”

5) “My dad is a captain for AA, if that is relevant.”

6) “Great survey! “

7) “I don’t feel comfortable with a mass of people being flown without a pilot. There are an Infiniti of possibilities with what could happen at any time, and I don’t think a computer program is going to be able to always do something it think will work in theory. With cars like Tesla, the automated driving is more like autopilot on steroids - it doesn’t change lanes or make turns, it just goes with the traffic. And it doesn’t always work that well, but there is always someone behind the wheel to take over in the event of an emergency. Plus, having a self-flying plane, I feel, is more incentive for online terrorists to hack a plane full of people. If a plane full of packages gets hacked and crashes, that’s unfortunate, but if it’s a plane with people in it... I don’t know, I just don’t like the thought of self-flying passenger planes. “

8) “I am not comfortable flying and I know technology can fail as can humans they should have both...”

9) “My source of ambivalence is lack of knowledge regarding safeguards and protocol in case of emergencies. With that information, all worries can be alleviated.”

10) “Can’t imagine it ever being safe enough. And I come from a family of private and military pilots and worked five years for a company that builds jets “

11) “I hope there’s never a passenger plane without 2 pilots in the cockpit. “

12) “Automation will put a lot of low skilled workers out of a job. What will we do with them? I am amazed we haven't had terrorists try to take down an airliner with a drone. Accidents will be difficult to avoid with thousand of drones in the air...we'll see.”

13) “We could never trust the lives of people to a computer. Especially one that is vulnerable to software issues and security risks. Passenger or Cargo aircraft should always have two pilots on board at all times. (Remoting into a compromised aircraft would be impossible). This would cause some serious issues in the aviation industry and could lead to heightened risk of terrorist attacks. Fully autonomous planes are a worse idea than autonomous cars.”

14) “Thanks for the opportunity. Pilotless flying is a possibility in some situations and drone delivery has more potential.”

15) “I don't want to die from a computer glitch. A human brain is so far beyond the best ARTIFICIAL " intelligence" we can create. A piolet has skin in the game.”

16) “I perceive that the technology for autonomous aircraft is probably more advanced already than autonomous cars because of military and space exploration tasks that have been happening for decades. That is why I feel it would be safer to be in an autonomous aircraft rather than a commercial flight with only one pilot and no other human or fully autonomous backup for human error.”

17) “To remove the pilot (s) means to remove any chance of manual override in the event of a computer malfunction or in the event it’s a single pilot operation, if the pilot has a medical issue in flight the ability to have a human take over control.”

18) “Pilotless commercial aircraft? something (such as an AI) will have to control the aircraft. So really asking about non-human piloted aircraft, perhaps?”

19) “We still have people on trains and ships. I believe the DOT would make them unmanned before air travel. Then small drones like delivery, small cargo, large cargo, small travel, then 121 in that order. I never see 121 ops becoming fully autonomous. There are too many factors that I believe can’t be properly handled by a remote operator. Even with one pilot there is too much to do in the current layout of aircraft. I believe Boeing and airbus would need to build a completely new flight deck layout before they could properly single pilot a 121 flight.”

20) “Personally, I believe that fully autonomous commercial aircraft are a ways down the road. There are certainly other factors that must go into the R&D process, such as electrical failures, how it would integrate with ATC, how GA aircraft would be affected, etc. “

21) “I have a general fear of flying. It’s completely irrational but exists.”

22) “Unless a transponder type system is added to ALL drones our aviation system is in danger, just take a look at the drone reports in the vicinity of LAX. It’s an accident waiting to happen. The relays for drone’s pilots to talk to ATC hasn’t been perfected either, than needs to be fixed also; too much of a delay.”

23) "I generally don't trust anything operated completely by machinery without oversight from a human being."

24) "Most of my work comes from taking off and landing without a pilot, the middle part seems like it would be fine"

25) "I have been in the air traffic control business for 34 years and have seen a huge amount of change in that time. UAS and self-driving cars are inevitable."

26) "I would not get on a airplane without at least one pilot as a backup "

27) "I am optimistic, other the heavy traffic areas for both car and planes."

28) "I'm not sure we will get to fully autonomous commercial passenger flights. Even though I think the technology can support it."

29) "I genuinely believe we are almost there in terms of unmanned aircrafts. Now, it's all about getting the travelers acclimatized and comfortable with it. One question in this survey is missing the "none" option. Think it's where you ask whether the user has taken any pilot course or not. "

30) "I trust computers more than people."

31) "As a retired ATC, there are way too many variables to ever be programmed into a total pilotless aircraft or drone."