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OBJECTIVES

The University Aviation Association publishes the Collegiate Aviation Review International throughout each calendar year. Papers published in each volume and issue are selected from submissions that were subjected to a double-blind peer review process.

The University Aviation Association is the only professional organization representing all levels of the non-engineering/technology element in collegiate aviation education and research. Working through its officers, trustees, committees, and professional staff, the University Aviation Association plays a vital role in collegiate aviation and in the aerospace industry. The University Aviation Association accomplishes its goals through a number of objectives:

- To encourage and promote the attainment of the highest standards in aviation education at the college level
- To provide a means of developing a cadre of aviation experts who make themselves available for such activities as consultation, aviation program evaluation, speaking assignment, and other professional contributions that stimulate and develop aviation education
- To furnish an international vehicle for the dissemination of knowledge relative to aviation among institutions of higher learning and governmental and industrial organizations in the aviation/aerospace field
- To foster the interchange of information among institutions that offer non-engineering oriented aviation programs including business technology, transportation, and education
- To actively support aviation/aerospace oriented teacher education with particular emphasis on the presentation of educational workshops and the development of educational materials covering all disciplines within the aviation and aerospace field

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1-7-2020

Training Capacity of the Fixed Wing FAA Part 141 Flight Schools within the United States

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Discussions have been held in classrooms, industry forums and in the media about the looming pilot shortage. Discussion to date has primarily focused on causal factors, and forecasting industry need for pilots; there is little research on where those pilots are going to come from. A study was conducted in the Fall of 2018 to quantify the pilot training capacity in the United States, focusing on FAA Part 141 certified flight schools associated with University degree programs. This information will be used to help the FAA and industry members make informed decisions and plan for the future. In total, 33 schools participated in a survey, ranging in size from 1,700 students to 11. Findings indicated that a lack of CFI's was the most common limiting factor, followed by lack of aircraft. 14 of the 33 schools were at or above 100 percent capacity. Several other metrics were surveyed, including costs, total pilot output, training duration, and CFI attrition, in order to build a broad picture of the state of pilot training within the United States.

Recommended Citation:

Thomas, R.M. & O'Toole, N.M. (2020). Training Capacity of the Fixed Wing FAA Part 141 Flight Schools within the United States. *Collegiate Aviation Review International,* 38(1), 1-11. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/7957/7343

Discussions have been held in classrooms, industry forums, and in the media about the looming pilot shortage. The impact of the 1,500-hour rule, the cost of training, and increasing retirements are just a few of reasons leading to the cause for the shortfall. A report released at the Paris Airshow by C.A.E. (2017), a worldwide training organization, forecasts that the industry worldwide will need an additional 255,000 pilots by 2027 to sustain its growth. The report adds that more than half of these pilots have not yet begun training. The RAND Corporation published a study that supports the hiring and industry growth trend (McGee, 2015). The RAND study has a broader scope and maps the supply chain that should be providing a steady stream of pilots to fulfill the demand.

The Airline Safety and Federal Aviation Administration Extension Act of 2010 (PL 111-216) was a significant change to the airline hiring practices and prompted a body of research to look at various impacts of the law. Smith, NewMyer, Bjerke, Niemczyk and Hamilton (2010) studied the backgrounds and training records of more than 2,100 regional airline pilots in order to identify characteristics of a successful first officer candidate. Flight programs associated with university degree programs were identified as the primary source of pilots for airlines in the United States. Smith et al. (2010) showed that: 1) pilots graduating from an Aviation Accreditation Board International (AABI) accredited program, 2) with a bachelor's degree were two of the five criteria for determining a high success rate through pilot training. Therefore, this study chose to focus primarily on those Part 141 certificated flight schools that were associated with a university degree program. An expansion of the research by Smith et al. (2017) looked at numerous other factors including the number of hours of dual flight instruction an applicant logged. These hours were compared before and after implementation of PL 111-216. Overall the amount of dual given has increased since the law passed. In maintaining a constant pipeline of pilots, attracting and maintaining a core of flight instructors is critically important. A study looking at the effects of Public Law 111-216 on collegiate aviation provided a good overview of what aviation program administrators are expecting and experiencing as a result of the law (Depperschmidt, 2013). Of the schools surveyed, 41% were AABI accredited and an additional 22 schools were looking at AABI accreditation in response to PL 111-216. Additionally, PL 111-216 was seen as detrimental to collegiate aviation programs by 67% of the survey respondents; and, 41% perceived the law to be detrimental to program enrollments (Depperschmidt, 2013). While the current study does not directly address the effects of PL 111-216, it would appear that student enrollment has not been adversely affected. In an additional study, Casebolt (2015) assessed student perceptions of PL 111-216, providing insight as to the career aspirations of students enrolled in public and private collegiate aviation programs. Of the 283 students surveyed, 65% of them aspired to be commercial pilots, 8% wanted to fly for the military, 16% corporate, and 11% selected “other.” Based on the results of this survey, only 76% of the pilots training in collegiate aviation programs would funnel directly into the industry to resolve the shortage.

The question remains: where will these future pilots come from? The United States is the world leader in training pilots but does the country have the training capacity to fulfill pilot demand? The Federal Aviation Administration (FAA) (2018) issued 7,019 commercial airplane single-engine land certificates; 6,615 commercial multi-engine land certificates; and 2,024 certificated flight instructor certificates in 2018. Are all those pilots destined for the airlines? The goal of this survey was to create a clearer picture of the flight training environment and it is associated limitations. It aimed to quantify the training capacity at FAA-approved Part 141 Pilot Schools associated with university degree programs. Along with the current capacity of these schools, the survey also gathered information regarding the current output of training schools, the duration of the training, the cost of training, and an exploration of factors that limit training capacity.

Methodology

An online survey was sent out in the Fall of 2018 to 108 schools identified from the Federal Aviation Administration's website listing of 14 Code of Federal Regulations (CFR) Part 141 Pilot Schools. These schools provide flight training in support of a university degree program. Participants identified from the FAA's website listing of pilot schools were called to obtain an email address for the appropriate personnel to complete the survey. Thirty-three of the 108 schools completed the survey, yielding a response rate of 31%. Each school participant was given a weblink to an online survey and presented with an electronic consent form. The participants were then presented with the online survey to gather information and provided with an opportunity to add additional comments. The researchers followed up with a phone call to the participants to ensure there were no technical glitches in the administration of the survey and increase response rate. A list of the survey questions is in Appendix A.

Results

The survey responses were divided into two groups: 1) programs with fewer than 250 students; and, 2) programs with more than 250 students. After reviewing the data there was a natural separation between larger schools and smaller school size. The division at 250 students was a decision made by the authors aimed at separating schools into two groups by size—large and small—to make better comparisons across the different flight school sizes. Eleven of the schools had more than two hundred and fifty students enrolled in the flight program and twenty-two had fewer than two hundred and fifty students enrolled in the flight program. Twenty-five of the 33 schools (76%) had minimum entry requirements for flight students. Those requirements were not defined in this survey. Eighteen of the schools (55%) had programs that were accredited by the Aviation Accreditation Board International.

The average student load for schools with more than 250 student enrollments was 589 (*SD* = 486.53). The average for schools with less than 250 student enrollments was 83 students (*SD* = 41.48) (see Table 1). Cumulatively, the schools surveyed were at an average of 97% of their maximum capacity. Fourteen of the 33 schools have enrollments at or above one hundred percent capacity (see Table 2). Eighty percent of these students on average were focused on the airlines as their career goal.

Table 1
Current Student Load

School Size	*M*	*SD*	Total
All	252	365.98	8,303
250+ Students	589	486.53	6,484
<250 Students	83	41.18	1,819

Table 2
Maximum Student Capacity

School Size	M	SD	Total	% Max Capacity
All	259	364.29	8,547	97%
250+ Students	579	500.72	6,365	102%
<250 Students	99	50.60	2,182	83%

The larger schools had a higher proportion of international students. The overall percentage of international students was 6.2%. The larger schools had an enrollment of 13.3% international students. Sixty-seven percent of the schools also provided flight training under 14 CFR Part 61, though this training made up less than 10% of the overall training (see Table 3).

Table 3
Part 61 Training Conducted at Part 141 Pilot Schools

School Size	Conduct Part 61 Training	% of Schools Conducting Part 61 Training	% of Training under Part 61
All	22	67%	8.80%
250+ Students	9	82%	11.10%
<250 Students	13	59%	7.65%

Eighty-two percent of the schools indicated a lack of CFIs limited their ability to produce pilots. Forty-two percent of respondents suggested that a lack of aircraft adversely impacted their school’s ability to train pilots. Additional factors listed were limitations of local air traffic control, low enrollment, cost of training, lack of Airframe and Powerplant (A&P) mechanics, and ramp space. All schools reporting a CFI shortage reported needing an average of 9.2 (*SD* = 11.1) flight instructors to meet demand. Schools with more than 250 students have an average of 79.5 (*SD* = 69.1) instructors and schools with less than 250 students had an average of 11.8 instructors (*SD* = 5.8). Results are presented in Figure 1 and Table 4.

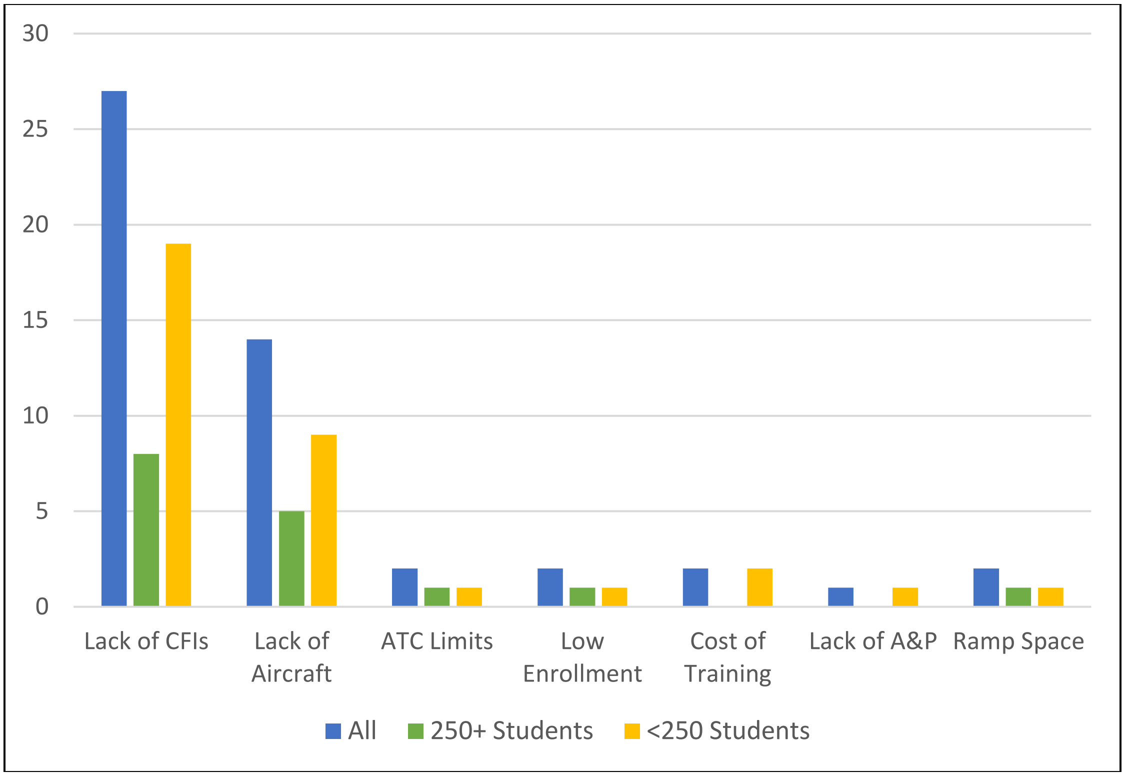

Figure 1. Limiting Factors of Part 141 Pilot Schools.

Table 4
Current CFI Totals and Shortage

School Size	Total CFIs	CFI (*M*)	*SD*	CFI Shortage	Shortage (*M*)	SD
All	1,055	33.0	49.2	267	9.2	11.1
250+ Students	795	79.5	69.1	162	18	16.1
<250 Students	260	11.8	5.8	105	5.3	4.4

The average student output per year was broken down by certificate type (see Table 5). Commercial single engine land and commercial multi engine land averaged 45.8 (*SD* = 75.2) and 44.2 (*SD* = 75.4) respectively at all schools. CFI certificates issued annually averaged 23.8 (*SD* = 34.9) from all schools.

Table 5
Student Output Per Year

	Comm ASEL			Comm AMEL			CFI		
School Size	Total	*M*	*SD*	Total	*M*	*SD*	Total	*M*	*SD*
All	1,144	45.8	75.2	1,104	44.2	75.4	596	23.8	34.9
250+ Students	842	105.3	114.8	877	109.6	109.8	473	59.1	44.8
<250 Students	302	17.8	11.0	227	13.4	10.1	123	7.2	6.1

The cost and duration of flight training required to achieve a Commercial Pilot multi-engine land certificate required an average of 29 months (*SD* = 7.28), at an average cost of

$53,983.13. An Initial Flight Instructor Certificate and Instrument rating (CFII) required an average of 7.2 months (SD = 5.62) and cost a mean of $12,685. The mean cost of training from Private Pilot to CFII was $66,669.08 and averaged 36.7 months to complete (SD = 8.16). See Tables 6-8)

Table 6
Time and Cost of Training – Private to Commercial AMEL

School Size	Months	SD	Cost
All	29	7.28	$ 53,983.13
250+ Students	30	7.78	$ 58,403.13
<250 Students	29	7.23	$ 51,625.80

Table 7
Time and Cost of Training – Flight Instructor Initial and Instrument

School Size	Months	SD	Cost
All	7.20	5.62	$ 12,685.95
250+ Students	7.45	7.08	$ 9,226.50
<250 Students	7.08	5.05	$ 14,662.79

Table 8
Time and Cost of Training - Private to Flight Instructor Instrument

School Size	Months	SD	Cost
All	36.7	8.16	$ 66,669.08
250+ Students	37.9	7.65	$ 67,629.63
<250 Students	36.1	8.51	$ 66,288.59

CFIs work an average of 18.2 months (*SD* = 7.94) from the time they graduate until they leave to other employment. See Table 9.

Table 9
Time for CFIs to leave after graduation

School Size	Months	SD
All	18.2	7.94
250+ Students	15.0	7.27
<250 Students	19.8	7.99

Flight schools with greater than 250 students lose an average of 47 (*SD* = 35.57) CFIs per year. Flight schools with less than 250 students lose an average of 6 (*SD* = 3.68) flight instructors a year (See Table 10).

Table 10
Number of CFIs leaving per year

School Size	M	SD
All	20	35.57
250+ Students	47	51.74
<250 Students	6	3.68

Anecdotally, survey participants pointed to other issues affecting their flight training department. One participant noted large flight training delays due to a lack of FAA Designated Pilot Examiners (DPE's) to conduct check rides. Another noted that the potential drawbacks of a pilot pathway program saying,

> An additional challenge occurs when airlines hire CFIs in the middle of a semester. Delta Propel promises not to, but no other airline we work with demonstrates any sensitivity to pulling a CFI mid-semester, thereby leaving the hired instructor's students.

While 82% of all schools stated that the CFI shortage was affecting their ability to train, one survey participant pointed out that even having enough CFI's does not solve the problem,

> The biggest challenge that we see is the lack of CFIs . If you do not produce the CFI yourself then it is almost impossible to find. Once we do have the CFI then they are working multiple jobs because of the health care / part time employee rules [can only work an average of 29 hours per week].

One participant summed up their perspective,

> As an industry, we need to motivate all pilots to want to be CFI's to start their careers. That is the big issue in our program. We have good manpower right this minute, but it is fragile—and we don't want to hire just anyone to be a CFI because they are one. We still need to be selective.

Limitations

The relatively low response rate limited data reliability. The current study has limitations, the first being a low response rate. While several of the larger pilot schools participated in the study, having a greater level of participation would help increase the overall accuracy of the data. Additionally, some responses were derived from estimates from the schools. Additionally, some collected data would benefit from further clarification. For example, when discussing the CFIs, the survey did not ask if the flight instructors were full time or part time employees. While this survey focused on 14 CFR Part 141 Pilot Schools, there are other avenues for flight training like the military and Part 61 flight instruction that are not included in the data.

Conclusion

The 33 schools that completed the survey trained a total of 1,144 commercial single engine pilots and 1,104 commercial multi engine pilots. These certificate issuances represent 16% and 17% of *all* of these respective airmen class certifications issued in 2018. The participating schools trained 596 certificated flight instructors this is 29% of the total number of flight instructor certificates issued to pilots between the ages of 18 and 25 in 2018. While flight schools are training a significant percentage of the total number of flight instructors, these pilots are averaging 18 months of service as a flight instructor. The average total cost of flight training for a new student to earn a CFII certificate was $66,669.08, with an average completion time of 36.7 months. The survey results confirm what is already known by many flight school administrators. Airline hiring is generating a lot of interest in aviation careers. Flight schools are at or over capacity. Primary factors limiting the ability to train more pilots is the lack of available CFIs and training aircraft.

Recommendations for Future Research

Future research could repeat and expand on this survey in an effort to analyze trends in the training industry and gather data from more participants. It is hoped this information will be used to help the FAA, flight school administrators, and industry members make informed decisions and plan for the future.

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Appendix A

Research Questions

1. Name of Pilot School
2. If yes, please specify the college or university Name of point of contact
3. Email address for point of contact
4. Phone number for point of contact

Note that items 1, 2, 3, and 4 will only be used for follow-up questions and will not be used in any report or presentation of the data.

5. Is your flight program affiliated with an accredited college or university?
   a. Yes
   b. No
6. Does your college or university aviation/flight degree program possess AABI accreditation?
   a. Yes
   b. No
7. Do you have any screening or minimum requirements for pilot school applicants?
   a. Yes
   b. No
8. What is the current number of flight students enrolled in your FAA approved 141 pilot school?
9. What percentage of your flight students are international students?
10. Do you complete any flight training under Part 61?
    a. Yes
    b. No
11. If yes, what percentage of your training is completed under Part 61
12. What is the maximum number of flight students you able to train concurrently at your FAA approved 141 pilot school?
13. What is the limiting resource/factor(s) that limit your ability to reach maximum student output (select all that apply)?
    a. Lack of CFIs
    b. Lack of Aircraft Availability
    c. Low student enrollment
    d. ATC/Airspace saturation
    e. Other (please specify)
14. How many CFIs do you currently employ?
15. If you are short of CFIs, how many more would you need?
16. What is your current annual output of Commercial ASEL students?
17. What is your current annual output of Commercial AMEL students?
18. What is your current annual output of Flight Instructor -Initial students?
19. What is the mean time (in months) to complete your program from Private through Commercial ASEL & AMEL)
20. What is the mean cost (flight cost only, not tuition or fees) to complete your program (from Private through Commerical ASEL & AMEL?
21. What is the mean time (in months) to complete your program’s Flight Instructor ASE and Flight Instructor Instrument-Airplane?

22. What is the mean cost (flight cost only, not tuition or fees) to complete your program's Flight Instructor ASE and Flight Instructor Instrument-Airplane?
23. What is the mean time (in months) your graduates stay employed at your flight school before leaving for an airline first officer job?
24. Do you have any flow through programs or airline hiring agreements?
    a. Yes
    b. No
25. How many airlines do you have agreements with?
26. How many of your students are enrolled in flow through programs?
27. What percentage of your graduates are focused on an airline career path?
28. On average, how many flight instructors leave your flight school for an airline first officer position per year?
29. Open Comments:

Collegiate Aviation Review
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1-8-2020

Fatigue in Collegiate Flight Training

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Fatigue-related problems are not new in the aviation industry and have been a contributing factor to more than one-fifth of all aviation accidents. Using an online survey instrument, this exploratory study investigated how 138 collegiate flight students interact with fatigue during their flight training. Overall, students recognize they are fatigued and that it has a negative impact on their flight training. Many of the students identify the proper strategic adjustments that they need to make to manage fatigue, such as reducing workload, getting more sleep, and keeping a regular sleep schedule. However, they do not seem to be making those adjustments. They indicate that they lack enough quality sleep, have high workloads, and do not keep a regular sleep schedule. Findings from this study are consistent with recent flight training studies and can assist the collegiate flight training community in the management of student fatigue.

Recommended Citation:

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Everyone experiences fatigue from time to time, but fatigue in high-risk industries such as transportation is an especially-dangerous risk factor. Fatigue-related problems are not new in the aviation industry. Fatigue contributed to a substantial number of aviation accidents from the mid-1970s to the early-1990s (Caldwell, 2005), and the National Transportation Safety Board (NTSB) made over 50 fatigue-related recommendations between 1972 and 2018 (NSTB, 2018). Fatigue was a contributing factor to 20.3% of all investigations by the NTSB conducted between 2001 and 2012; and of those, fatigue was a contributing factor in 23% of aviation-related transportation accidents during the same period (Marcus & Rosekind, 2017).

The effects of fatigue can manifest in subtler ways than aircraft accidents or incidents. Fatigue insidiously infiltrates the lives of pilots long before they become the subject of NTSB investigations, and the long-term effects of fatigue can have lasting impacts on pilots. Fatigue is a precursor that may be uncovered during accident investigations; and, it has been established that the long-term effects of fatigue on pilot performance is a critical safety issue that warrants mitigations (International Air Transport Association [IATA], International Civil Aviation Organization [ICAO], & International Federation of Air Line Pilots' Associations [IFALPA], 2011). Human factors training introduces new pilots to fatigue, its effects, and methods to avoid fatigue. This study provides educators a chance to see the prevalence of fatigue within a collegiate flight training environment.

Purpose of the Research

There has been very little research conducted regarding fatigue in flight training (Levin, Mendonca, Keller, & Teo, 2019) This research aims to expand our understanding of the impact fatigue has on students in a collegiate flight training environment. McDale and Ma (2008) investigated the effects fatigue had on a group of flight instructors at part 141 flight schools. This research investigates the same issues related to flight students at a collegiate Part 141 flight school.

The role of the university within a person's life is debatable, but behavioral changes are often the result of education. The behavioral changes that occur can be positive or negative, depending on social and structural determinants of health. The social determinants of health "consist of policies and environments that support access to education, provide relevant resources for health (e.g., contraception), and create opportunities to enhance young people's autonomy, decision-making capacities, employment, and human rights" (U.S. Department of Transportation, 2012, p. 1634). Collegiate flight programs act as a structural means to provide opportunities for young adults to interact with positive social determinants of health by educating them about how their behaviors affect their flight performance and long-term well-being. This research will help clarify how flight students interact with fatigue to help shape human factors training into a relevant curriculum that incorporates the needs of students.

Collegiate aviation students will be members of the professional pilot workforce and play a vital role in fatigue risk management systems. Collegiate flight programs have the opportunity to shape students' attitudes and knowledge about fatigue, which will help inexperienced pilots effectively managing their own fatigue.

Aside from educating new pilots about professional standards and norms, flight schools certified under Part 141 also operate full flight schedules that carry their own inherent safety risks. We can also improve operational safety in collegiate flight training courses by teaching college student-pilots to manage their own fatigue during flight training. Improving fatigue-related human factors training also has the added benefit of improving the safety within collegiate flight training environments.

Three primary research questions provided the focus for this research:

1. How do students evaluate their fatigue and how do they believe it impacts their flight training?
2. What do students perceive to be the causes of their fatigue?
3. What lifestyle adjustments do the students believe are necessary to manage their fatigue?

Literature Review

An industry-wide strategy has been developed to combat the risks associated with fatigue in aviation. Fatigue management (FM) "generally refers to the identification of fatigue risk and the implementation of strategic controls" (Avers, Hauck, Blackwell, & Nesthus, 2010, p. 52). Avers, Hauck, Blackwell, and Nesthus (2010) describe three distinct stakeholder groups that are necessary for effective FM: (1) regulatory agencies; (2) operating organizations; and (3) the pilots. A fourth stakeholder group--the research community--also contributes to FM strategies.

The regulator mandates maximum duty time and rest requirements for flight crews in operational environments. The operator, or airline, influences the fatigue culture in two ways. First, the airline schedules its pilots and must, at a minimum, follow duty limitations regulations. Second, airlines may implement Fatigue Risk Management Systems (FRMS) to identify and mitigate risks associated with fatigue. The pilot is responsible for managing their own fatigue and for being *fit for duty* (U.S. Department of Transportation, 2012). Fitness for duty means a pilot is "physiologically and mentally prepared and capable of performing duties assigned" (U.S. Department of Transportation, 2012, 2012, p.1). The research community is the fourth stakeholder group involved in FM. The research community should inform and educate other FM stakeholders to find ways to reduce the risks associated with operating aircraft in fatigued states. Their research also contributes to the body of literature used by other stakeholder groups to address fatigue-related issues.

Definition of Fatigue

In their thorough review of FAA fatigue research, Avers and Johnson (2011) correctly describe fatigue as a "complex state" (p. 88). Understanding fatigue requires a definition that reflects the complex nature of the construct of fatigue. Literature provides many definitions of fatigue that lack comprehensiveness and consistency (Avers & Johnson, 2011; Lee & Kim, 2018; Noy et al., 2011; Phillips, 2015). Using a common definition for fatigue will help the aviation research community develop comprehensive research agendas covering all aspects of fatigue.

A complete definition of fatigue adequately describes the complex nature of the condition of fatigue, the causes of fatigue, and the consequences of fatigue (Phillips, 2015). A multi-dimensional construct with such immediate safety risks deserves a definition that reflects the complex nature of fatigue, its antecedents, and its outcomes (Avers & Johnson, 2011; Noy et al., 2011). A consistent, comprehensive definition of fatigue will allow the research community to strategically investigate these different aspects.

A unified definition of fatigue provides transportation researchers with a theoretical framework to guide future fatigue-related research. Because previous definitions of fatigue in transportation research are too divergent to be useful, Phillips (2015) proposes a new definition of fatigue and "claims that by delimiting the origins, state, and consequences of fatigue, a 'whole' definition would help make explicit for different transport researchers, aspects of fatigue that different studies do not measure, as well as those that they do measure" (p. 49). A common, unified definition of fatigue in transportation research allows the research community to monitor and categorize fatigue research into different aspects of the complex construct of fatigue. According to Phillips (2015):

> Fatigue is a suboptimal psychophysiological condition caused by exertion. The degree and dimensional character of the condition depends on the form, dynamics, and context of exertion. The context of exertion is described by the value and meaning of performance to the individual; rest and sleep history; circadian effects; psychosocial factors spanning work and home life; individual traits; diet; health, fitness and other individual states; and environmental conditions. The fatigue condition results in changes in strategies or resource use such that original levels of mental processing or physical activity are maintained or reduced (p. 53).

This definition of fatigue has three basic parts: origin, state, and consequences. First, *origins* refer to the sources of fatigue, which can be mental or physical exertion and varies along with working conditions. Next, *state* refers to the psycho-physiological condition, characterized by objective and subjective measures of fatigue. The fatigued condition is directly dependent on the type and degree of exertion (physical or mental effort). Lastly, *consequences* refer to the behavioral changes that result from fatigue (Phillips, 2015). The results of this research follow this three-part framework.

College Students in Aviation

College students engaged in flight training are different than other members of the piloting workforce because they are typically younger and less experienced than counterparts. Persons of all ages need quality sleep to maintain their physical and phycological health, but college-age students who are in their late adolescence are more susceptible to the effect of fatigue and face greater safety risks when operating airplanes for flight training because their physiological needs differ (Pink, 2018).

Collegiate aviation is a rare intersection in the aviation industry because its members are young college students, a unique population in the industry. Pilots in this age group interact with fatigue differently than older pilots. Aside from their novice status among the piloting community, collegiate aviation students are unique because most are still in the developmental process of adolescence, albeit in the latter stages (American Psychological Association, 2002; Curtis, 2015; Sawyer et al., 2012). They are known for impulsivity and peer pressure (Sawyer et al., 2012). As adolescents, they possess different behavioral characteristics, such as staying up late, sleeping in on weekends, and have different sleep needs than fully-developed adults.

The sleep patterns of college students are notorious, and their lack of sleep creates conditions conducive to chronic and acute fatigue and their related symptoms (Lund, Reider, Whiting, & Prichard, 2010). College is a "a time of minimal adult supervision, erratic schedules, and easy access to over-the-counter (OTC), prescription, and recreational drugs" (Lund, et al., 2010, p. 125). The academic demands of school and the social demands of college life relegate sleep to a tertiary status. According to Lund et al. (2010), only 29.4% of college students report getting enough sleep. They noted that average sleep time for college student (*N*=5,401) was 7.02 hours (*SD*=1.15) (Lund et al., 2010, p. 125).

Levin, Mendonca, Keller, and Teo (2019) through a mixed methods exploratory study investigated how pilots in the collegiate flight training environment mitigate fatigue through lifestyle factors and how they rank those solutions for fatigue management. The most effective solutions that the participants identified for fatigue mitigation were obtaining more sleep, reduced workload, and time management of their flight and class workloads. Several themes through qualitative inquiry were found, including; socializing and late night electronic use delayed student's bed times, excessive noise and light in the dorm environment led to sleep disturbances, and school workload time spent working frequently left participants sleepless.

Research Methodology

This study used a survey methodology to understand how students at Part 141 pilot schools feel they were impacted by fatigue. This study replicates the questionnaire of McDale and Ma (2008) who assessed the impacts of fatigue on flight instructors at Part 141 pilot schools in the U.S. The instrument used was not validated and some questions were altered to suit the new population. The internet-based questionnaire, data collection methodology, and the informed consent notification were approved by the university institutional review board to ensure high ethical standards in the research process. All participation in the study was voluntary.

Sampling

This study used a convenient, non-probability sample to identify participants for the survey. A department student listserve was used to email a survey link to all students enrolled in the flight program. The researchers acknowledge that the convenient sampling technique limits the generalizability of the results (Cohen, Manion, & Morrison, 2011). This exploratory study shows the prevalence of fatigue-related issues within the study sample and possibly other flight training environments.

Participants

The participants in the study were undergraduate students engaged in flight training at a certified Part 141 pilot school at a state university in the U.S. The students were enrolled in a two-year flight degree and a four-year aviation management degree. All participation in the study was anonymous and voluntary.

Data Collection and Analysis

Data were collected over two different periods. The first data collection period was from November 9, 2017 until December 8, 2017, and the second data collection period was from April 8, 2019 until April 17, 2019. Both of these time periods had a high number of operational activities.

The researchers added an additional question to the second questionnaire to ensure that each participant only contributed one set of responses. The first question on the second questionnaire asked respondents if they had taken the survey during the first data collection period. Respondents who indicated they previously participated in the first survey were removed from the second group of respondents. The nature of the variables used in the survey limit the analysis for the current project to descriptive statistics.

Results

The results are divided into three major section based on the different elements of Phillips' (2015) definition of fatigue: (1) the psychophysiological state; (2) the exertion expended and the context in which it occurred; and (3) the strategic behavioral adjustments that are made as a result of fatigue. A demographics section provides a general picture of the respondent population.

Response Rate

The number of students enrolled at the time the of data collection determined the population for this study. A total of 132 students were enrolled in the flight program, and a total of 60 students responded to the questionnaire, yielding a 45% response rate for the first data collection period. The enrollment during the second data collection period was 153 students, with 68 students responding, resulting in a 44% response rate during the second data collection period (Institutional Research and Studies, 2019).

Demographics

The respondents were students enrolled in a collegiate flight training program at a flight school certified under 14 C.F.R. §141. A large majority (80.47%) of the 128 respondents were between the ages of 18-24, and the remaining respondents were older. Survey respondents reported enrollment in the range of aviation flight-related courses offered in the curriculum, with the largest concentration of students training for instrument rating (26.78%). The curriculum at the institution where the data were collected offers private pilot, instrument rating, commercial pilot, multi-engine, and flight instructor courses. Nearly two-thirds (66.33%) of the 98 respondents had only a private pilot certificate while the remaining one-third of respondents had an instrument rating, or other flight certifications and ratings. Most of the respondents (60.71%) had less than 200 hours of total flight time

A Sub-optimal Psychophysiological State

Phillips (2015) explains that fatigue is both a subjective (psychological) and objective (physiological) condition. This research does not address the objective, physiological state of fatigue. Rather, the survey questions asked the respondents for their perceptions of fatigue, a subjective rating.

Respondents indicated awareness of their fatigue and believed it impacted their flight training. Using a ten-point Likert-type scale, respondents rated the degree to which they were aware of their own fatigue, with 1 being the least aware and 10 being the most aware of their own fatigue. A weighted average of the responses was 7.40, with a median and mode of 7 (30% of respondents). In addition, 95% of respondents (*n* =121) indicated that fatigue effects the quality of their flight training.

The respondents provided information indicating how they experience fatigue during flight operations. Using a five-point, Likert-type scale, the respondents indicated their levels of agreement to the six statements contained within Figure 1.

Responses to these statements are listed in Figure 1. Those respondents who claim they *strongly disagree* with the previous statements potentially do a good job managing their fatigue, whereas those responding as *neutral*, *strongly agree,* or *strongly disagree* may need more guidance on effective fatigue management strategies.

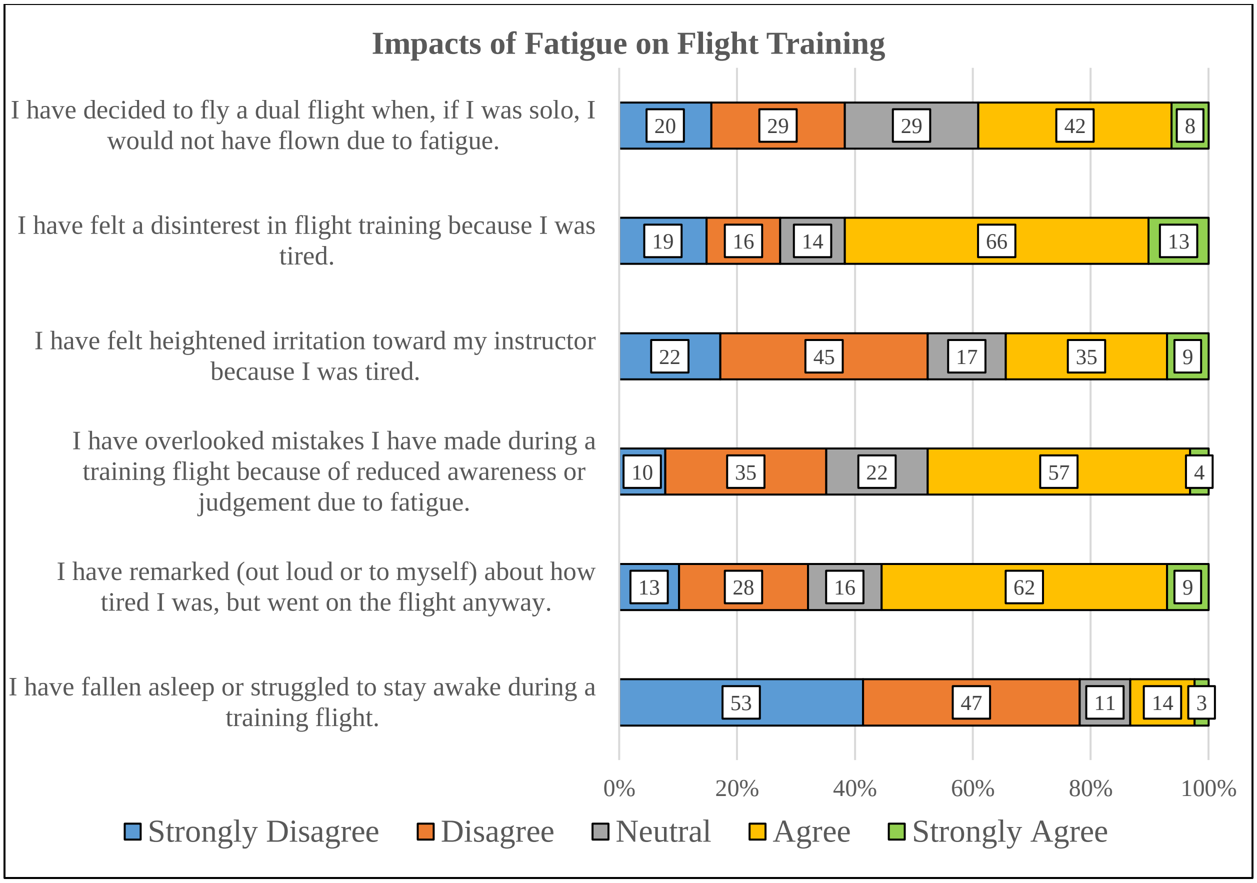

Figure 1. Impacts of Fatigue on Flight Training.

Exertion

Fatigue is caused by exertion, which occurs in different contexts. This section provides information on the context of fatigue like weekly workloads, sleep habits, and other lifestyle factors. Respondents also ranked factors that contributed to their fatigue.

Academic workload. The primary workload of a student enrolled in a collegiate flight program is the effort related to the university's core curriculum and courses required by for the aviation-related major, including flight courses. Respondents reported being in school for most of the week. Nearly 66% of the 128 respondents answering this question indicated that they attend class five days a week. Three-quarters of respondents (*n* = 96) indicated they attend class between 3-5 hours each day. Most of the respondents (76.56%) reported a full-time academic schedule, of 12 or more credit-hours per semester. Respondents most commonly reported being enrolled in 15-18 credit hours, which is 1-2 courses over the standard, full-time workload.

Sleep habits. Respondents reported information about their sleep habits. This section reports results of the respondents' quantity and quality of their sleep. Quantity of sleep refers to the number of hours respondents slept per day, either through regular, nightly sleep or by napping. Quality of sleep refers to the number of times respondents' sleep was interrupted per night and whether their sleep made them feel rested.

Quantity of sleep. Respondents showed different sleeping habits on the weekdays than on the weekends. Overall, the respondents reported an average of 7.89 hours of sleep per night during the week and an average of 9.04 hours of sleep per night during the weekend. Respondent sleep and rise times also differed from weekday to weekend.

Respondents reported sleep patterns on *school nights* and *non-school nights*. Half of respondents (*n* = 64) reported going to bed between 11:00 pm and 12:00 am on nights when they have school the next day. An additional 29 respondents (22.66%) go to bed sometime after midnight on school nights. The remaining results are displayed in Figure 2 which shows a pattern that shifts toward later bedtimes on non-school.

Similar to the manner bed times shifted to later times on non-school nights, wake times also shifted later on non-school mornings. Wake times on school days were distributed normally, with the highest concentration of respondents waking between 7:00 am and 8:00 am (see Figure 3). Wake times on non-school days show a distinctly different reporting pattern. The majority of respondents (57.81%) indicate that they wake sometime after 9:00 am on non-school days.

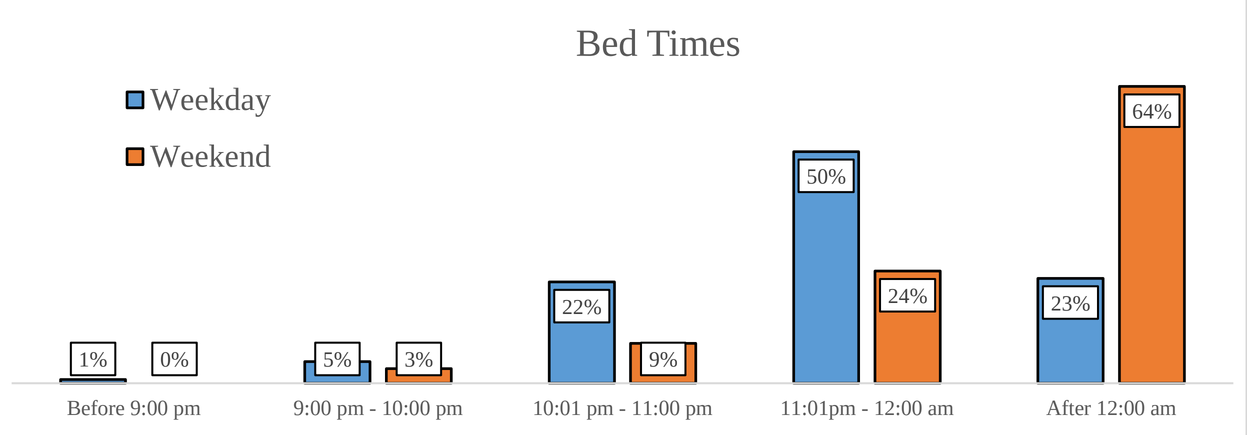

Figure 2. Reponses to this question indicate the degree to which fatigue-related symptoms impact flight training activities.

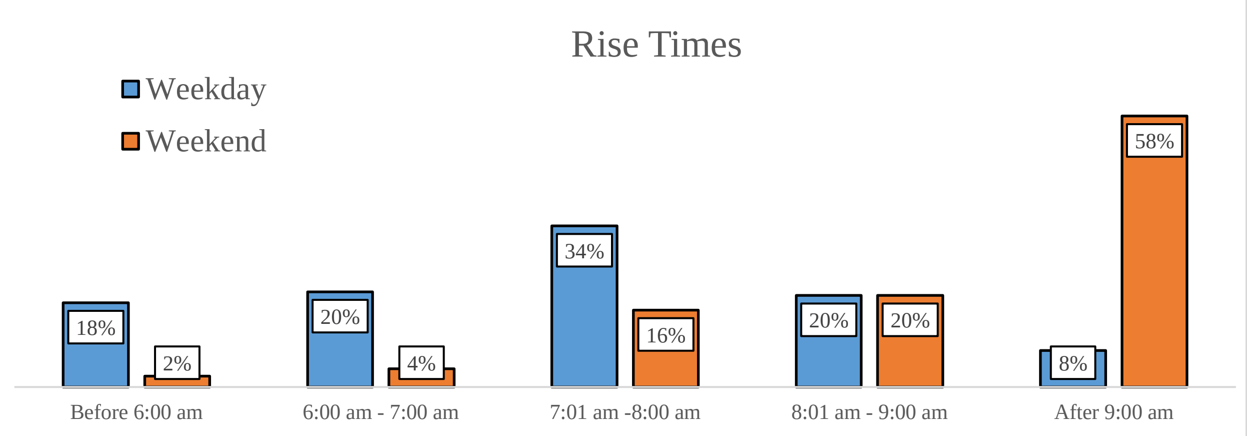

Figure 3: Bed Times and Rise Times on Weekdays and Weekends

Quality of sleep. Respondents reported how often their nightly sleep was interrupted and whether or not they were refreshed after a night's sleep. Figure 4 displays the number of times the respondents' sleep was interrupted each night. More than half (57%) of the 128 respondents claimed their sleep was interrupted one or fewer times each night, almost a quarter (23%) had sleep interrupted twice each night, and the remaining 20% had their sleep interrupted three or more times each night. Additionally, 38% respondents reported feeling dissatisfied with the quality of their sleep, a proportion that closely mirrors the number of respondents who reported two or more interruptions every night.

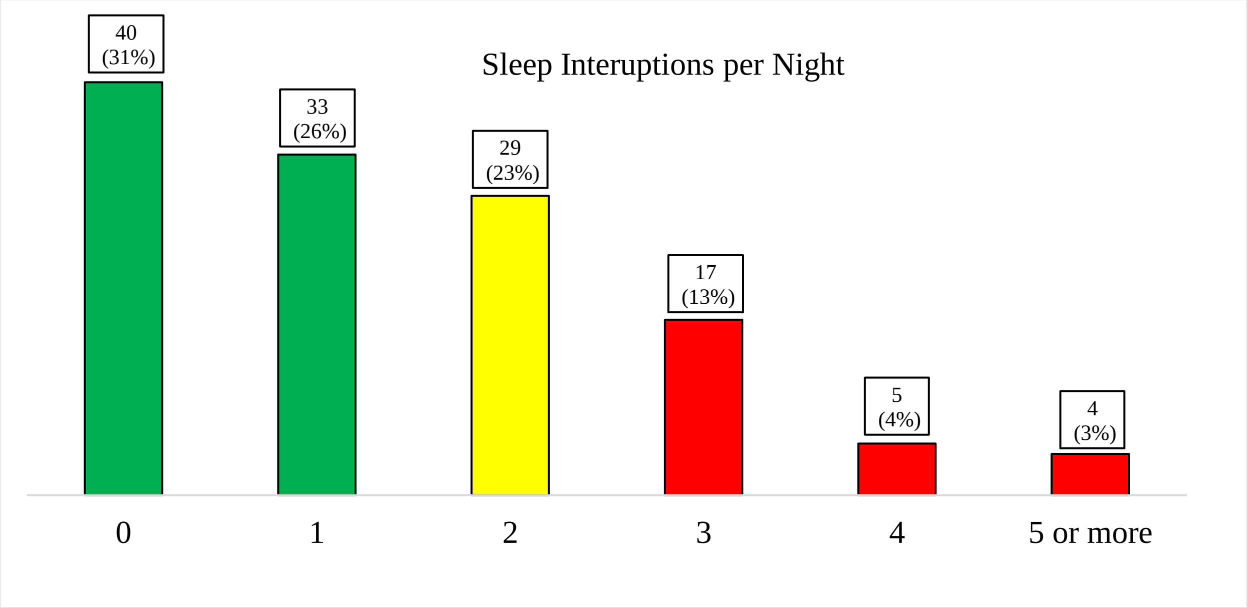

Figure 4. Number of Sleep Interruptions per Night.

Using a Likert-type scale, participants weighted their levels of fatigue during flight operations that occured at different times of the day. On days students conducted flight operations, the majority of respondents indicated that their fatigue levels were greatest during early morning operations, between 6:00 am and 9:00 am. They also reported their levels of fatigue to be the greatest during the same time period on days without flight operations. The lack of quality sleep was consistent with previous research from Levin et al.(2019), that found 66% of the respondents indicated that they were not getting a fully adequate quantity or quality of sleep each night.

Factors Contributing to Fatigue. Participants ranked a list of 12 factors that could contribute to fatigue, and ordered them from least influential to most influential on their fatigue. Of the list of 12 factors that contribute to their fatigue, flying after a long day was shown to be the most influential on their perceived fatigue levels. Conversely, sleeping next to a partner was shown to be the least impactful on their fatigue. Figure 5 displays the ranking of the remaining factors the respondents believe impact their fatigue levels.

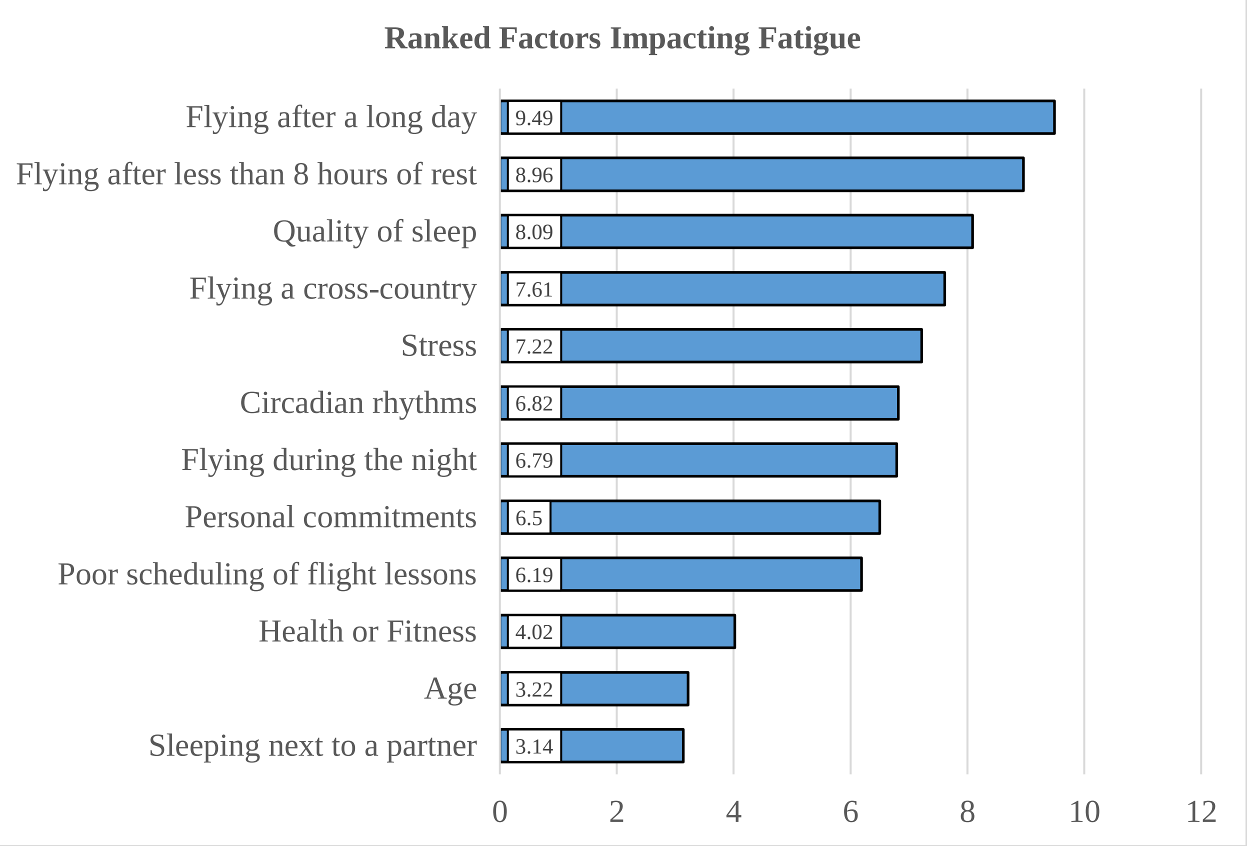

Figure 5. Ranked Factors Impacting Fatigue of Collegiate Flight Students.

Strategic Adjustments

Phillips (2015) states that exertion-induced fatigue in transportation industries causes some sort of strategic cognitive adjustment in order to maintain performance while fighting against symptoms of fatigue. Motivation has a large influence on the strategic adjustments made by transportation workers in the operational environment where safety is a prime concern. The authors extend the concept of strategic adjustments to include lifestyle or behavioral changes that can have a positive influence on chronic or acute fatigue.

Respondents ranked a list of solutions they could use to manage their own fatigue. Figure 6 shows a ranked list of factors respondents believe could prevent fatigue during flight training.

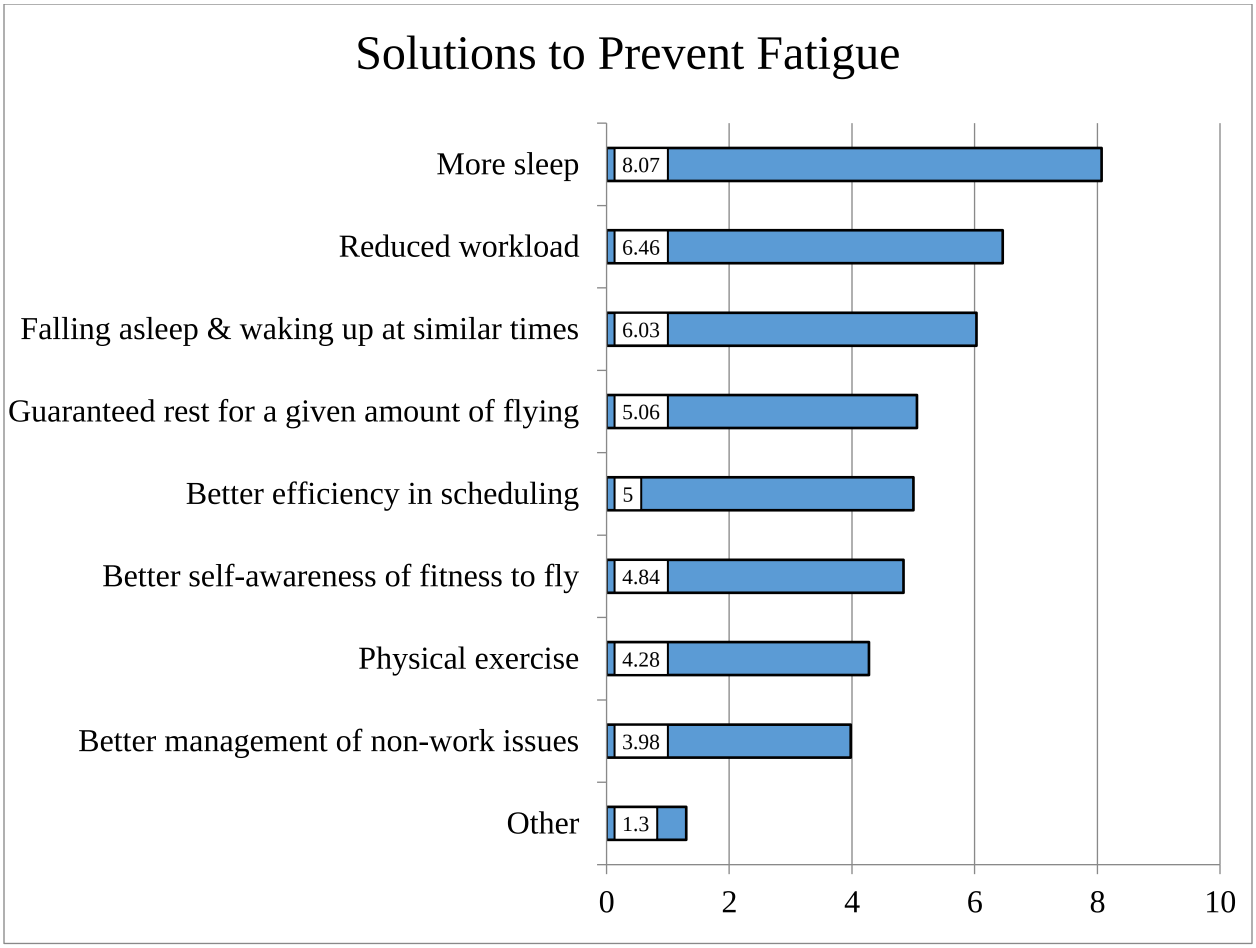

Figure 6. Ranking of solutions to prevent fatigue.

Discussion and Conclusions

This section provides an assessment of the results gathered from the responses to the questionnaire. Phillips (2015) definition of fatigue is used here as a guide to discuss the implications of the data collected through the questionnaire. The results of the survey provide insight into the way collegiate flight students interact with fatigue, which helps the fatigue management stakeholders develop curricula, regulations, and policies aimed at mitigating the adverse impacts of fatigue within the aviation industry. Many of the findings support previous research by Levin et al. (2019).

A Suboptimal Psycho-Physiological State

Nearly all (95%) of the respondents believe fatigue impacted their flight training. This result reveals the prevalence of fatigue within the sample, justifying more attention toward educating pilots about the interactions of fatigue and flight training.

The data contained in Figure 1 reveal some troubling realities about how pilots interact with fatigue and flying. Each of the situations in Figure 1 represent an undesirable interaction with fatigue and flight training. Disagreement or strong disagreement with each scenario is the most desirable, or *safe* response. Neutral responses, agreement, or strong agreement with any scenario represents risks to flight training or an *unsafe* response. Figure 6 repeats the scenarios from Figure 1 but dichotomizes responses between safe and unsafe behaviors to show the prevalence of unsafe responses to these scenarios.

Falling asleep while flying is certainly an obvious warning sign, but other less obvious warning signs exist within the data. For example, almost 73% of the 128 respondents attributed disinterest in their flight training to being fatigued. The prevalence of fatigue-related apathy and other, less obvious unsafe behaviors are displayed in Figure 7. This is important because it clearly shows that unsafe, fatigue-related behaviors impact collegiate flight training.

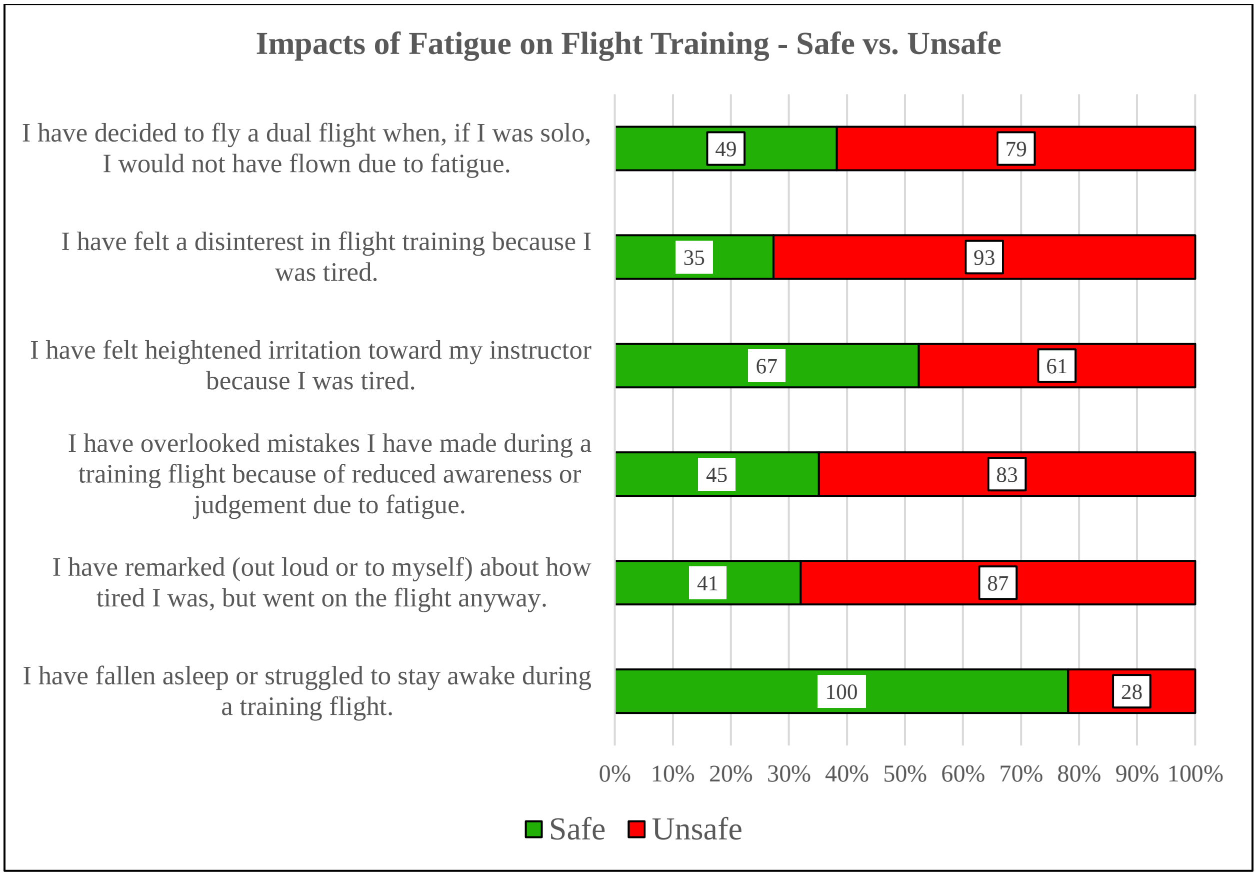

Figure 7. Safe and Unsafe Impacts of Fatigue on Flight Training

Exertion

Nearly all respondents claimed that fatigue impacted their flight training. Thirty-eight percent of respondents claimed to feel refreshed after a night's sleep; both indicate fatigue-related risk factors. According to their responses, respondents were sleeping enough during the week and weekends, and their academic workloads and weekly school schedules indicate they dedicated a substantial amount of energy on school-related activities. Their irregular sleep habits may reveal more about their fatigue than their workload or amount of sleep.

The times the respondents reported going to sleep and waking both shifted at least one hour later on the weekends compared to the weekdays. It would appear that most of the participants within this study had sleep patterns that were consistent with other studies investigating the sleep habits of college students. The late bed times and early wake times are consistent with other studies that have investigated the sleep quality and quantity of college students (Eliasson, Lettieri, & Eliasson, 2010; Buboltz, Brown, & Soper, 2001). Although the respondents may get adequate sleep, their shifting bed and wake times from the weekdays to the weekends may contribute to the prevalence of fatigue with in the study sample.

Interrupted sleep is low quality sleep. Waking one or two times per night may not impact the overall quality of sleep, but havingsleep interrupted more than twice each night can reduce the overall quality of sleep and lead to fatigued conditions. Twenty percent of the respondents reported having their sleep interrupted more than two times each night, which is certainly impactful on their ability to recharge.

Some students managed their fatigue by supplementing their nightly sleep with naps. Napping provides the opportunity to increase the daily quantity of sleep or make-up for poor sleep caused by excessive interruptions. Previous research indicated that naps improve physiological and psychological performance (Pink, 2018). The results indicated that many students do not nap to help manage their sleep debt. Nearly 33% of respondents indicated they napped to manage their fatigue. Most of the students who reported napping indicated that they usually took a nap in the early afternoon or evening, which fortunately are the best times of the day to nap based on normal circadian rhythms (Pink, 2018).

Strategic Adjustments

Lifestyle choices are integral to proper fatigue management. Strategic lifestyle adjustments are necessary to react to various demands that affect fatigue. Students identified that the best strategies for managing their fatigue were to sleep more, reduce workload, and keep a regular schedule. Many students did not rank exercise high in importance for managing fatigue. This is similar to the findings by Levin et al., (2019). Research has shown that physical exercise has a tremendous benefit for lowering stress and increasing the quality of sleep (Pilcher, Ginter, & Sadowsky, 1997; Trockel, Barnes, & Egget, 2017).

Overall, the students recognize they are fatigued and that it has a negative impact on their flight training. Many of the students identify the proper strategic adjustments they need to make to manage fatigue (reduce workload, more sleep, and keep a regular sleep schedule). However, they do not seem to be making those adjustments. They indicate that they lack enough quality sleep and have high workloads and do not keep a regular sleep schedule.

Threats and Limitations

A lack of face validity is a one major threat to the results of this study because of insufficient operationalization of the construct of fatigue (Drost, 2011). Although Phillips (2015) provided a framework for communicating and discussing the results of the survey, it was not used to shape an operational definition for the survey respondents to use as a guide for the questionnaire. Because each participant used their own, independent, subjective definition of fatigue, the authors cannot be sure the responses to the questionnaire that related to the construct of fatigue were similarly understood by all respondents.

The non-probability sampling technique used in this study limits the generalizability of the data generated from the questionnaire. Because the convenient sample is not representative of the entire collegiate flight student population, the results of this research can only be generalized to the students who responded to the survey. These students, however, are not unlike other collegiate flight students, and the results can be considered to help develop a complete picture of the interaction between collegiate flight students and fatigue.

This research replicated a survey used in previous research. The instrument used was not a validated instrument. The categorical nature of the questions adapted from previous research limited the analysis to descriptive statistics rather than more sophisticated inferential analysis. Future research in this area should focus on using questions that yield data that generate more meaning than a simple descriptive analysis.

Recommendations

The results indicate that collegiate aviation education may have a problem with fatigue similar to other parts of the aviation industry. While the results are not generalizable, it is not hard to imagine that the conditions at institutions similar to the study institution may yield similar findings. This needs to be studied so that we can help the future aviation professionals recognize and combat fatigue.

Several recommendations for further research come from the findings of this study. First, expanding the sampling frame of this study to a regional or national sample to improve generalizability of the study. .Second, broadening the scope of the research to include all aspects of collegiate aviation education rather than just flight training may indicate if fatigue is endemic to aviation education as a whole or limited to flight training. Third, numerous respondents in this study indicated interrupted and ineffective sleep patterns. Studying collegiate aviation student sleep patterns may shed light on how the sleep habits of aviation students differ from those of the general collegiate student population. Finally, if this study were replicated or expanded upon, the survey instrument should be updated to reflect current survey best practices that would be conducive to a greater depth of analysis.

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Developing a Taxonomy for Success in Commercial Pilot Behaviors

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Human error has been well studied in aviation. However, less is known about the ways in which human performance maintains and contributes to aviation safety. The lack of data on positive human performance prevents consideration of the full range of human behaviors when making safety and risk management decisions. The concept of resilient performance provides a framework to understand and classify positive human behaviors. Through interviews with commercial airline pilots, this study examined routine airline operations to evaluate the concept of resilient performance and to develop a taxonomy for success. The four enablers of resilient performance, anticipation, learning, responding, and monitoring, were found to be exhaustive but not mutually exclusive. The tenets of resilience theory apply in airline pilot behavior, but operationalizing a taxonomy will require more work.

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Human error is thought to account for 80% of aviation mishaps (Shappell & Wiegmann, 2001). As a result, human error has been well studied in aviation (Helmreich, 1997; Kontogiannis & Malakis, 2009; Wiegmann & Shappell, 1999). Researchers and practitioners are able to speak a common language due to the development of a well-accepted taxonomy, the Human Factors Analysis and Classification System (HFACS) (Wiegmann & Shappell, 2017). The widespread acceptance of models such as Threat and Error Management (TEM) have helped valuable concepts of human error move into operational settings as diverse as aviation, medicine, and nuclear power. (Boy & Schmitt, 2013; Helmreich & Musson, 2000). Most data sources in aviation, such as the Aviation Safety Reporting System (ASRS), the Aviation Safety Action Program (ASAP), and Line Operations Safety Assessments (LOSA), are *event* or *error* driven, which enables and reinforces the study of error.

However, much less is known about how human performance actively builds and enables system safety and efficiency (Holbrook et al., 2019). In complex, high reliability systems such as aviation, resilience has emerged as a key factor in safe and efficient operations. Resilient performance occurs when a system can "adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions." (Hollnagel, 2011, p. xxxvi). Studying how human performance contributes to system resilience can offer a new perspective on how to improve system performance and safety, and will offer a more complete picture of the role humans currently play in complex systems. As Holbrook et al. (2019) point out, understanding the full range of human contributions to system performance is critical at a time when the role of the human in the aviation system is changing.

Background

Safety I and Safety II

In its earliest days, aviation safety was reactive, with most safety improvements driven by mishap investigations. With the introduction of incident reporting systems and the development of hazard identification and risk mitigation strategies, aviation safety entered a period of proactive safety management, in which mishap precursors could be identified and mitigated prior to mishaps occurring. This approach, known as *Safety I*, concentrates on identifying, trapping, and mitigating error in order to reduce the number of negative outcomes to as low as reasonably practicable (Hollnagel, 2018; ICAO, 2009).

A number of challenges emerge with the Safety I approach as systems become safer. First, data is only systematically collected on operations with error or negative outcomes, so as operations become safer, a smaller and smaller proportion of actual operations are analyzed (Holbrook et al., 2019). Therefore, opportunities to learn and improve become increasingly limited. Second, the focus on prediction and prevention of negative outcomes does not accommodate unknown or unknowable threats. Third, if safety is measured by the absence of events that are extremely rare, it becomes increasingly difficult to assess the impact of system changes (Holbrook et al., 2019). Finally, it is intuitively obvious that studying failure when you are trying to ensure success tells only part of the story. In a comment first attributed to Marit de Vos of Leiden University, it is as if we are trying to learn about marriage by studying divorce (de Vos, 2018).

Data Sources

A key tenet of Safety Management Systems is the collection and analysis of safety data, so that the impact of changes to the system can be measured and monitored (ICAO, 2009). Aviation has a rich variety of data sources that drive safety decision making. The Aviation Safety and Reporting System allows anonymous reporting of incidents from private and commercial pilots, air traffic controllers, mechanics, dispatchers, and cabin crew (NASA, 2019). The Aviation Safety Action Program fulfills a similar function among air carriers and repair stations (FAA, 2002). The Flight Operational Quality Assurance (FOQA) program collects vast amounts of data on routine flights that is analyzed by individual operators for exceedances and trends. Finally, the Line Operations Safety Assessment program uses expert observation of routine flights to identify threats and errors, based on the Threat and Error Management model (FAA, 2014). Finally, the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA) collect data on aircraft mishaps and publish detailed accident reports and analyses.

These data sources primarily focus on errors or incidents, and therefore do not represent the population of routine and ordinary flights. Robust data sources on successful flights are lacking. Therefore, most safety recommendations derive from a non-representative data set, and the routine and successful operations that make up the vast majority of commercial aviation operations are not documented.

Human Error

The abundance and quality of data concerning human error has made it possible to create a taxonomy of human error that has been widely accepted. The Human Factors Analysis and Classification System was derived from extensive analysis of aviation mishaps and incidents, and has been applied to diverse industries outside aviation (Wiegmann & Shappell, 2017). HFACS has enabled a common language to be used in government, academia, and industry, and among researchers as well as practitioners. The ubiquity of HFACS has made it a powerful tool in identifying and addressing problems in human performance. Similarly, ASRS categorizes incidents using a taxonomy that focuses on outcomes and failures in human performance, which has resulted in a body of rich and consistent information about adverse events and errors (NASA, 2019).

However, no such common vocabulary exists for discussing *successful* behaviors that actively contribute to system safety. The lack of a taxonomy to categorize and classify positive behaviors adds to the difficulty of studying successful performance.

Resilience Theory

Safety II depends not only upon reliable data sources and a common vocabulary, but also on a theoretical underpinning. Just as models of human error are anchored by theories of human information processing and cognition, so models of successful behaviors must be anchored by theories of human and system performance. Accident causation models have typically been linear, leading to the approach that preventing bad outcomes involves preventing or mitigating precursors. However, some mishaps cannot be explained by linear models. Rather, they are the result of a complex interplay of events that affect each other (Woods, 2017). In this model of accident causation, safety results from the ability of a system to accommodate these events. Resilience theory concentrates not on the response to the specific disturbance, but on the system capabilities that allow it to accommodate the disturbance.

Resilient performance is thought to be enabled by four key system attributes, specifically, the ability to:

- Anticipate future events or situations
- Monitor both its own performance and environmental factors
- Respond to expected and unexpected events
- Learn from experience

These four abilities form a model of resilient performance based on the underlying theory of resilience (Hollnagel, 2011).

Problem

The study of error has been instrumental in achieving the safety improvements that commercial aviation has enjoyed. However, the reduction in negative outcomes creates problems for using the Safety I approach to further improve safety. As negative outcomes decline, the proportion of flights studied becomes smaller and less representative. Further, the impact of safety interventions becomes very difficult to assess. Also, a system that concentrates on identifying and mitigating threats may become vulnerable to threats that cannot be predicted. Instead, a Safety II approach is needed that supplements Safety I by examining the qualities that allow a system to respond flexibly in response to threats and disturbances, both anticipated and unexpected.

The Safety I approach has been successful in improving commercial aviation safety, but further safety advances cannot depend only on reducing the occurrence of negative outcomes. Safety in complex systems depends on the ability of a system to accommodate disturbances. System resilience depends upon behaviors that reflect the key attributes of anticipation, monitoring, responding, and learning. However, the error and event-based reporting approach common in commercial aviation does not fully capture the range of pilot behaviors corresponding to the key attributes of system resilience. As a result, much of the pilot’s contribution to system resilience is not measured, and therefore not studied systematically.

In order to understand how system resilience is built and maintained, data must be collected on routine successful operations. Currently, aviation has rich data sources and robust taxonomies to study error, but insufficient ways to identify and categorize success.

Purpose

The purpose of this study is to identify behaviors that increase system resilience in routine commercial airline operations, and to begin to articulate a taxonomy for behaviors that contribute to system resilience. Data on successful routine performance in commercial aviation is not systematically collected or analyzed in a way that allows for exploration of the qualities and attributes that enable system resilience. LOSA assesses routine flights, but focuses on error management. FOQA records information on routine flights, but the data analysis focuses on exceedances, rather than the data that might correspond to corrections that prevent exceedances. These data sources are tremendously valuable, but incomplete in the effort to study the contribution of routine pilot performance to system resilience. This study aims to fill a small part of that gap by studying specific events that involve unexpected or unplanned events and exploring pilot behaviors that contributed to successful conclusion of these flights.

Significance of the Study

The Safety I approach of reducing negative outcomes has natural limits as systems become safer. Further improvements in safety and efficiency must come from expanding data sets to include analysis of successful outcomes in order to understand the antecedents of successful performance as well as the antecedents of unsuccessful performance. Safety II is still in its early stages of acceptance. This study adds to the growing body of literature that uses a Safety II approach to understand the full range of human performance contributions to system resilience. Learning more about successful human behaviors that contribute to system resilience can help training organizations cultivate and enhance resilient performance. Further, with the increase in interest in autonomous systems in aviation, it is vital to understand the human contribution to system performance so this ability can be accounted for in any new system design.

Research Questions

Can commercial airline pilot behaviors be classified according to the four key attributes of resilient performance?

Can a taxonomy of resilient performance be articulated from investigating airline pilot behaviors in routine operations?

Methodology

This project used a qualitative, case study approach based on incident debrief interviews with commercial airline pilots. The study was designed to utilize purposeful sampling of the participants' viewpoints and expert opinions regarding their decision-making processes in aviation. Qualitative research is the traditional method for discovering a deeper understanding of a subject in a way that quantitative-only data cannot give us.

The interviews were based on the critical incident approach in which a participant was asked to recall a particular type of event (Hobbs, Cardoza, & Null, 2016). The interview protocol contained a greeting, description of the purpose of the research, event prompt, follow-up questions, and space for reflective notes. Using research questions developed by NASA, the researchers developed an open-ended question with follow up questions to probe for deeper meaning (Holbrook et al, 2019). The interview questions are presented in Appendix A.

Institutional Review Board permission was obtained from the sponsoring university prior to any participant recruiting or data collection. To maintain the confidentiality of the participants, all identifying information was redacted from the transcripts.

A case study methodology was employed to examine the various aspects of the pilots' thought processes within the theory of resilient performance. This case study was designed to bring the researchers to a deeper understanding of this issue, adding depth to what is already known about this phenomenon. As a result, 16 unique perspectives were obtained, analyzed, and placed into specific themes for the purpose of addressing the research questions.

Participants

Sixteen pilots from major U.S. airlines were recruited for participation in this study. Fourteen pilots were actively flying for a major airline (including eight captains and eight first officers); and, two were actively flying for a regional carrier (one captain and one first officer). Saturation of the data was met through this sample by ensuring that adequate quality data was collected to support the study; no new information was expected to be added to the emerging patterns that would enhance or change the findings of this study.

The 16 purposely-selected participants were pilots from different airlines, which allowed for different perspectives from a cross section of cultures, experiences, and situations. In the data collection and analysis process, each participant read and signed a confidentiality consent form, was assigned a code to ensure confidentiality and privacy was maintained.

A high degree of validity was designed into the research process. The first step to ensure validity consisted of inter-rater reliability (IRR) training. Interviewers discussed potential biases and then met to create mock interviews, thereby ensuring consistency of questions and follow up techniques. Next, the researchers ensured that an appropriate sample was selected, by interviewing both captains and first officers from different airlines. Finally, triangulation was also used to ensure validity. Interviews were conducted by three IRR-trained researchers in different locations. Once the interviews were complete, the researchers individually analyzed the data before meeting to compare and integrate their individual results.

Procedures

As an initial study, this data is intended to support a foundational understanding of pilots' thought processes and behaviors within resilient performance. As in any research, ancillary findings (which are not the primary target of the planned procedures) can greatly contribute to the results of this study. Further, understanding the thought processes in real-world situations was envisioned as a secondary function of this research.

The researchers voice-recorded each participant's discussion throughout the interview. A written transcript was developed for each participant after de-identifying each participant's information. Each of the participants' responses offered insight into their perceptions, opinions, and personal recommendations of airline operations. The MAXQDA qualitative analysis software was used to organize and analyze the data. The participants were assigned a sequential identification number (i.e. Participant 1 [P1]). Using the inductive approach to data analysis, the researchers then extracted key statements and phrases while organizing them into broad patterns that corresponded with the research questions and finally summarized what was communicated within each statement. From this extraction, the researchers identified primary themes.

While the researchers had specific interview questions that were asked during each of the semi-structured interview sessions, the interviewers also permitted the free flow of dialogue. This approach provided a broader set of information, yielding richer overall data than is presented in this discussion.

Through the data collection process, the researchers were able to freely engage with the participants, which yielded additional unexpected findings. While not initially planned, the additional dialogue provided a wealth of interpretive data to support the findings from the original structured research questions.

The data reduction process was helpful in further identifying patterns and alignment to the research questions. In the review of themes, the above connections were drawn based on similar participant responses and the interpretation of this data. It is important to be mindful that qualitative data analysis is ongoing, fluid, and sheds light on the broader study questions.

Limitations and Delimitations

This study included only pilots employed full-time with airlines based in the United States. Additionally, participants were limited to those who were available and willing to be interviewed. Purposive sampling allowed for the representation of a variety of airlines, but may have introduced other biases.

Results and Discussion

As an initial study, this data is intended to investigate the practical application of resilience theory in real-world setting. Holbrook et al. (2019) categorized behaviors in terms of strategies for resilient behavior, such as “Anticipate resource gaps” and “Anticipate procedure limits”. The authors focused on observable behaviors rather than underlying strategies, since the research objective was to develop a taxonomy of behaviors that an expert observer could use in safety audit setting. However, the theoretical framework and major categories were the same. Our intent was to begin a discussion among researchers and practitioners, rather than to prescribe an exact taxonomy. The model for the taxonomy is shown in Figure 1.

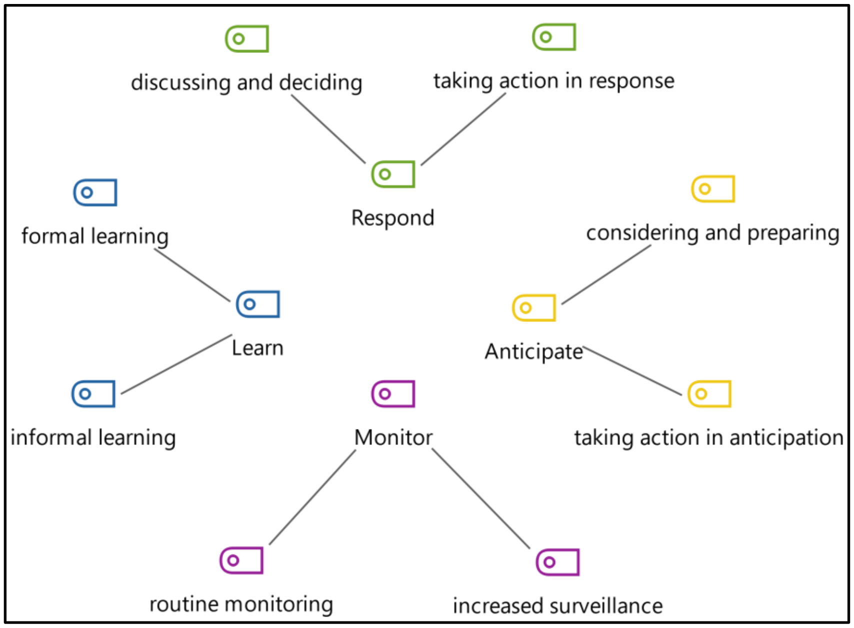

Figure 1. Taxonomy for observable behaviors of resilient performance.

The four categories of *Anticipate*, *Monitor*, *Respond*, and *Learn*, are discussed below.

Anticipate

When asked the first research question, *Were there things you were aware of at the start of your flight that you thought increased the likelihood that this event might occur during that flight?*, there were two themes identified in the data:

Considering and Preparing. These behaviors consisted of gathering information, discussing what to do, and deciding on action. For example, in response to noticing that an aircraft ahead got diverted, P9 stated, “Then we started talking to dispatch, and started trying to coordinate to go somewhere else in case in we needed to do that.” As P3 stated, ”Once we got up with the Washington Center frequency that was starting to do the traffic delays we had a plan in place so we knew once we got into holding we'd already calculated that we could hold for about 20-25 minutes before we'd have to go to our alternate.”

Taking Action in Anticipation. In some cases, pilots became aware of potential disruptions, and took action in anticipation of them. As P8 stated, “We knew thunderstorms were forecast, so we added extra fuel to give us maximum holding time.” During an uncertain maintenance delay, P13 explained “It's just really important to manage your sleep. And so I slept as much as I could during that day, not knowing when we were leaving.”

Monitor

When asked the second research question, *Were there things that you experienced during that flight that you though increased the likelihood that this event might occur?*, there were two themes identified in the data:

Routine Monitoring. Responses from pilots indicated there are known factors they routinely monitor on every flight, for example weather, crew rest, the aircraft interphone system, or traffic in the area. P4 stated “Just for myself, usually anytime I'm on a more than like an hour long flight pretty much as soon as I get up to cruise I update and monitor all my weather information. Just to have like the earliest heads up if something is starting to change. And that's when we first got up to cruise, I got an updated ATIS for Baltimore and it was already showing thunderstorms at the field.”

As another example, P9 stated “I was just flying from Charlotte to San Francisco, and I'd say probably almost, a little over halfway into the flight, I actually monitor the flight attendant conversations over the interphones. I'm sure like you guys have, we have a way to monitor their intercom conversation. So, I keep that available. I started noticing they were calling about a passenger that was having some kind of medical distress. So I became aware of something that could potentially be developing with a medical issue. And I typically just wait and let it play out and then eventually they're going to contact me and let me know. But at least now I have an idea that at least something's transpiring or beginning to transpire so I can start to... It lessens the startle effect later.”

Increased Surveillance. In addition, there were factors that pilots paid more attention to due to certain circumstances, for example holding and diversion of aircraft ahead on the flight path in areas of bad weather, fuel state when other aircraft were diverting for weather, and traffic in the area when conditions made VFR traffic likely. P6 stated “You know it was August in Miami. So, you always have to be aware of the potential for the airfield getting soft in the thunderstorms. Typically, in Florida they move through fairly quickly and we do have holding fuel for that contingency. And then sometimes there's a little extra. So, we look at the fuel more carefully based on experience with the weather and actual weather.”

P2 explained, “You know that busy airport on a VFR day you're going to have VFR traffic in addition to traffic that are filed with the FAA or you know… you've got guys that are not filing. So just more of an awareness that this trip I needed to be on my A game, you kind of keep an eye out for this basically.”

Respond

When asked the third question, *How did you respond to this event?*, there were two themes identified in the data:

Discussing and Deciding. This included gathering information, discussing alternatives, and deciding on action to take. For example, P8 stated “Between the two or three of us with dispatch, we continually monitored the weather and tried to make the best possible decision. Like I said, I was more for going to Dulles, which was open at the time, and they were both like, ‘Yeah, but Dulles, they've got that thunderstorm there, close by, and they're predicting it's going to move in. I think BWI is clear and a million, and we're going to be pretty safe going in there’. . . It was actually a little bit closer than Dulles, although either one of them were super close. Between the three of us, we gathered the information, made a decision we were all comfortable with. I was comfortable going with Baltimore.”

Taking Action in Response. This category included all actions taken in response to unexpected events or situations, for example following a checklist, initiating a divert or complying with a collision avoidance procedure. Pilot explanations of this were typically simple and direct. P4 stated "And then you break out the checklist. And do the normal things declare an emergency break out the checklist. Go ahead start running the checklists."

Learn

When asked the fourth question, *What did you learn from this event?,* every participant stated that learning from previous experience increases the safe operation of a flight. Every pilot specifically mentioned learning from previous events. This was the most discussed aspect of resilient performance for these pilots. Pilots stated that both *formal* and *informal learning* guided their actions.

Formal Learning. P16 stated "Training. . . So, any pilot that experiences any non-normal situation relies on their training methodology to solve the problem, resolve it." In addition, P15 included "Every year we train in the simulator for all kinds of different problems". Moreover, P1 included "I think there is pattern matching that goes on. I think I find in other emergency situations I have handled in my career there's pattern matching. It seems to me that, have I seen this kind of scenario before and it goes all the way back to my primary training we did simulated engine failures unexpectedly. So pattern matching to me can be helpful. Pattern matching can also retrieve some skills, some primal skills, positive primal skills that might help you deal with it."

Informal Learning. As P10 stated, "They may be able to trigger in their mind oh you know I talked to somebody about this once and I think that's really a huge hugely important thing in aviation is that is those little things that you have in your mind of past experiences and past stories that you've heard so that when symptoms of a problem do present themselves to you, you can kind of reach back to those tidbits of information and maybe use that to analyze and figure out what's going on in your situation."

Moreover, airlines have robust safety feedback programs. As P2 stated, "Well, we have a very robust ASAP, where we have access to a lot of information de-identified of incidents and events that occur. I think with a strong safety management system, through our FOQA program, our ASAP system and LOSA. I think there is power in learning and when you read these things you can be very arrogant and say well that would never happen to me. I look at it and say I could see that happening to me and... So I think learning about lessons learned from other people are very powerful."

In addition, P13 added "There's our debriefing afterwards. We talked about what had happened. Like I told my first officer, I said he did a fantastic job at coordinating with the flight attendants. Especially at the end when I was doing a lot of the flying, doing the diverting and talking to ATC, he did a lot of the behind-the-scenes stuff, which really helped. We debriefed what things could have gone better, what went well, and then how would we do things differently."

Ancillary Findings

As in any research, often the data collected yields information, ideas, or additional themes that were not anticipated. When this occurs, a rich and detailed set of findings can support the gap in the literature and further support the research questions. In this case, there were two major unintended findings that were common throughout the interviews. While this later theme may not be directly aligned to the original research question, it is related to the perceptions and opinions of the participants.

Enablers of Resilient Performance

Training. Training was a topic that was discussed in 12 of the 16 interview sessions. Every participant complimented the quality of training received from the respective airline. As P5 stated, “Yeah I lost an engine on takeoff a couple of years ago. And it was just sort of fall back on your training. . . Because you're trained for it all the time you know to lose an engine on takeoff.” P12 stated, “You see you start falling back on what you've been taught to do.” As P7 added, “yeah, simulator training. We had seen it before in the simulator. . . I followed the emergency procedures we were trained to do.”

Experience. In addition to training, experience was mentioned by 14 of the 16 every participants as a huge factor in how they responded to an event. As P1 stated, “On my last trip to Dulles, I mentioned it to the co-pilot what had happened, and if we were offered that again on an afternoon flight, that we would probably end up doing the same thing, or at least considering it.” P11 included “Experience because many airports that have construction anywhere near the end of the runway, have frequently had their instrument or glide slope and localizer antennas interfered with construction or vehicles driving right in front of them… Personal experience, since I was a private pilot, you just land the airplane.”

P4 handled an emergency by recognizing that *something just wasn’t right*, stating, “I guess I mean just from flying this aircraft for the past several years knowing what the speed schedule would be upon reaching the thrust reduction altitude it'll start commanding a nose down pitch attitude and the speed bug would switch up to two hundred and fifty. And just witnessing that not happening is something very different occurring. That was just outside of the normal pattern that you're accustomed to seeing.”

As P9 stated, “As experienced dictates, you try and avoid surprises, anything with startle effects, so I always anticipate or try to become cognizant of any potential threats to a flight. And like I said, the longer flights I'm aware that options could be limited to divert. A lot of international experience like yourself. So you realize there are areas where you have really limited options. You try and think ahead, "what would I do in this case?" Because you don't want to be caught behind the power curve and have a surprise and have to play catch up.”

Despite the importance of informal learning, pilots did not generally share these lessons through any established process. Rather, pilots reported sharing their lessons with others in one-on-one conversations, but generally they regarded what they learned as not significant enough to share through the more formal mechanisms available at their airlines. As Holbrook et al (2019) point out, “no methods exist to systematically report or capture this information. This is a missed opportunity for developing training, data systems, and procedures whereby operators could systematically benefit from others' lived experiences, not just their own" (p. 17). Further, several pilots noted that their airline experience differed from their previous military experience in this regard, with more opportunities to share informal lessons in their military flying background.

Crew Climate

Most participants discussed crew climate and crew coordination as major factors in their decision making, hence resilience. For example, as P14 stated, "But then you could almost call it if anything like a sort of like team building type thing. Because at that point we had kind of like faced, nothing major, but we faced an abnormal situation and worked through the issue and come to a conclusion there." As P7 stated," I learned that the people that I worked with during the emergency were awesome. The controllers were very helpful in getting us back around. Everything went very, very easily just because of the training, and the working together from the airline perspective." P8 added "The most important thing is having a crew that can work together. That can say, Hey, we're gonna check all the other stuff when we come to work, and just work together the best we can to handle any kind of a situation."

The contribution of the crew concept to resilience is an especially important topic to explore in future research, as the idea of single pilot operations gains more traction. Any changes to accommodate single pilot operations must also be able to incorporate the resilience that is an emergent property of team performance in the cockpit.

Categories Are Not Mutually Exclusive

It became apparent early in the interviews that often a response could be used in more than one category. For example, P9 stated "As experienced dictates, you try and avoid surprises, anything with startle effects, so I always anticipate or try to become cognizant of any potential threats to a flight. And like I said, the longer flights I'm aware that options could be limited to divert. A lot of international experience like yourself. So, you realize there are areas where you have really limited options. You try and think ahead, "what would I do in this case?" Because you don't want to be caught behind the power curve and have a surprise and have to play catch up." This example could easily fit into the categories of *Anticipate*, *Monitor*, or *Learn*.

Conclusion

Resilient performance, as a theory, appears to have practical application in aviation. Purposeful sampling of 16 airline pilots show resilient performance does occur on flights. The categories of Anticipate, Monitor, Respond, and Learn were exhaustive, but not mutually exclusive. Thus, the tenets of resilience theory are initially validated, but operationalizing a taxonomy will require more work.

Recommendations for the Instructional Environment

As noted previously, the highest response was in the category of Learning. Although each category is important in the decision-making process, opportunities to create better learning environments will continue to enhance safety. This gives great opportunities to enhance student learning with the incorporation of resilience theory.

As both formal and informal training were highlighted by the participants, three areas to create better learning for students:

Flight line Operations: as part of the brief/debrief time, instructors should build in scenarios where students need to think through a situation. Situations could include abnormal engine indications, unexpected weather, equipment malfunction, etc. This gives the student the opportunity to chair fly (practice on the ground) the thought process and resources available.

Curriculum Developers: a similar process can be used in any classroom setting (air traffic control, maintenance, UAV operations, etc.). Curriculum developers/instructors can build in “what would you do if” scenarios into lectures. This helps reinforce the law of primacy (learn it correctly the first time) for situations that may be encountered later in more stressful environments.

Capturing Positive Performance/Resilience: this gives opportunities to reinforce correct thought processes. Often times, people critique negative/incorrect application, yet fail to reinforce the overwhelming part the process that was done correctly. This is a great opportunity to correct faulty thoughts, but also praise and reinforce correct thought processes.

Future Research

Future research is suggested with a larger sample size, across numerous airlines, worldwide. Also, future research should include less-experienced pilots, to see if the theory holds at different levels of experience. Further, research should include different operational domains, such as flight instruction. Holbrook et al. (2019) discussed the need to be able to correlate safety data, such as FOQA data with crew behaviors. Future research should attempt to connect disparate data sources to develop a more robust and complete picture of resilient behaviors. Finally, carefully-scripted follow up questions should be introduced to include crew dynamics with resilient performance.

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Appendix A
Pilot Interview Protocol

Initial Question: Unplanned and unexpected events happen routinely during operations in the NAS. We are interested in how pilots make adjustments before, during and after these unplanned or unexpected events in order to maintain safe operations. Can you tell me about a specific unplanned or unexpected event that you have experienced in the course of routine operations?

Follow-up Questions:
- Were there things you were aware of at the start of your flight that you thought increased the likelihood that this event might occur during that flight?
- How did you know that this event might occur?
- How else might you have been able to anticipate that this event would occur?
- Were there things that you experienced during that flight that you thought increased the likelihood that this event might occur?
- What signaled/indicated to you that this event was about to occur, was occurring, or had occurred?
- How did you know what indicators of this event to look for during your flight?
- What other indicators could have alerted you to this event?
- How did you respond to this event?
- How did you know what to do in response to this event?
- If you had not already known what to do to respond to this event, how would you have figured out what to do?
- What did you learn from this event?
- How did what you learned impact the remainder of your flight or that operation?
- How did what you learned impact how you prepare for future flights or operations?
- Have you shared what you learned with others in your organization? How did you do that?
- In general, what practices are in place in your organization for pilots to share lessons learned?
- Is there anything further you’d like for us to know about this event that we haven’t already discussed?

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Depression, Anxiety, and Stress in Collegiate Aviators

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The purpose of this mixed-method research was to determine if students who are enrolled in a collegiate flight program exhibit significantly higher rates of depression, stress, and anxiety. This study compared collegiate flight students to non-professional flight students to determine whether collegiate flight students have higher rates of depression, anxiety or stress. In addition, this study sought to determine if there were higher depression, anxiety, and stress levels in upperclassmen (juniors and seniors) than in lowerclassmen (freshman and sophomore). These groups were compared to each other by using results from the DASS-21, a survey that measures depression, anxiety, and stress. There were no statistically significant results indicating no singular group is more or less prone to depression, anxiety, or stress.

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College can be a turbulent time for students as many of them are confronting new and complex experiences without the immediate and direct support from their parents, family, and friends. Some students may also be embarking on this new phase of life without the maturity or experience to handle many demanding events. Even for those who make the transition well it can be difficult to manage everyday responsibilities, academia, and adulthood (Pedrelli, Nyer, Yueng, Zulauf, & Wilson 2015). In general, this can be a challenging time but can become more so when an individual is dealing with mental illness.

More and more college students are dealing with mental illnesses, specifically depression and anxiety (Center of Collegiate Mental Health [CCMH], 2017 & 2018). Rates for students seeking counseling are increasing dramatically, yet some still attempt to handle things on their own. A recent study reported that rate of college students seeking treatment increased from 19% in 2007 to 34% in 2017 (Lipson, Lattie, & Eisenberg, 2019). The Center of Collegiate Mental Health, noted that anxiety and depression have had a clear growth trend over the past five years (CCMH, 2018).

Generally, while it appears college students are dealing with increasing levels of stress and mental illness, specifically depression, anxiety and stress, there may be some students pursuing academic majors which may cause even higher levels of stress due to the demands of highly-complicated course material and requirements of frequent skill demonstrations. One such major is *professional flight* where students are required to master not only the concepts of many complex courses such as meteorology, and aircraft systems but must also be able to demonstrate various flight maneuvers in varying types of environmental conditions. Studying to become a collegiate pilot may cause students to experience higher levels of stress (Blouin, Deaton, Richard, & Buza, 2014).

Mental health concerns can be a sensitive subject in everyday life and even more so in aviation. Even a suspicion of a mental health disorder can ground a pilot; and, if a diagnosis is made where the FAA deems the pilot is unable to meet requirements the pilot's certificate may be temporarily or permanently revoked (Morse & Bor, 2006). Therefore, it is an important topic to investigate as collegiate aviators will be entering into various flight roles upon their graduation, and a mental health disorder can cause a certified pilot to lose flight privileges.

Research Questions & Hypotheses

The researchers posed the following research questions:

1: Are students who are enrolled in a professional flight degree program more prone to exhibit significantly higher levels of depression, anxiety, and stress?

> H_0: The null hypothesis proposed would be such that there are no specific group of students who are more depressed, stressed, or anxious than the others.

H_A: Alternative hypothesis proposed that students enrolled in a collegiate flight program would have significantly higher levels of depression, anxiety, and stress than non-professional flight students.

2: Do upperclassmen (juniors and senior) students exhibit more depression, anxiety, and stress than underclassmen (freshman and sophomore) students?

H_0: The null hypothesis proposed would be such that upperclassmen do not exhibit significantly higher levels of depression, anxiety, and stress than underclassmen.

H_A: Alternative hypothesis proposed that upperclassmen would exhibit significantly higher levels of depression, anxiety and stress than underclassmen.

3: Is there an interaction between enrollment and academic stage (i.e., underclassmen vs. upperclassmen) such that differences between professional flight and non-professional flight students are greater for upperclassmen than underclassmen?

H_0: The null hypothesis proposed that there is not an interaction between upper/underclassmen in the collegiate aviation flight program regarding depression, anxiety, and stress.

H_A: Alternative hypothesis proposed that there is an interaction between upper/underclassmen in the collegiate aviation flight program regarding depression, anxiety, and stress.

Literature Review

Background

In 2016, more than 70% of high school students enrolled in a post-secondary institution (McFarland et al., 2018). In addition to attending classes, many students also need to establish independence, self-sufficiency, and how to manage new tasks, (Meadows, Brown & Elder, 2006). These new factors can lead to stress, anxiety, and depression—especially for students who have poor coping skills or those who are predisposed to mental illness.

For some college students, mental health issues may not be a new concern, as mental illness usually develops during adolescence and presents itself by age 24 (Andrews &Wilding, 2004; Hunt & Eisenberg, 2010; Mahmoud, Staten, Hall & Lennie, 2012). As an example, approximately 75% of young adults who are diagnosed with an anxiety disorder have their first episode by age 22 (Kessler et al., 2007).

Anxiety and depression disorders are the most common mental illnesses among adults (CCMH, 2017 & 2018). Approximately 18% of the United States population suffers from some type of anxiety disorder, with 6.7% suffering from Major Depressive Disorder (MDD) (National Institute of Mental Health [NIMH], 2017). Anxiety and mood disorders often co-occur and nearly half of those diagnosed with depression are also diagnosed with an anxiety disorder (NIMH, 2017; Sanderson, Di Nardo, Rapee, & Barlow, 1990).

Mental illness can plague college students in their everyday life causing ordinary activities to become difficult. Untreated mental illness in students can impact academic success, productivity, and incite substance abuse (Hunt & Eisenberg, 2010).

Mental Health Definitions

The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) published by the American Psychiatric Association (2013) is the authoritative guide used by health care practioners to provide a diagnosis for individuals dealing with mental disorders. The DSM-5 has been developed over time and is updated regularly to maintain currency with new research and breakthroughs in the mental health community. It is important to note, however, that not all practitioners utilize or rely solely on the DSM-5, but instead use it as part of their practice. Some mental disorders are clearly defined with clear boundaries and symptom clusters, yet many appear on a spectrum and can appearing with some or all symptoms. Many disorders are closely-related with shared symptoms with similar genetic and environmental factors (American Psychiatric Association, 2013). Some mental health disorders can be fleeting and solved with time, while others can be more pervasive and take years of care and help to address. Depression and anxiety disorders can be in both of those categories.

Depressive disorders. The most common feature of depressive disorders is a sad, empty, and irritable mood. Depressive disorders also include body changes and cognitive impacts that affect the individual’s ability to function for more than two weeks. Depression tends to impact the sufferer in everyday life making it difficult to complete daily activities and even get out of bed (NIMH, 2017). Specifically, in academia, depression can impact the student’s ability to learn and retain information (NIMH, 2017; Prince, 2015). Difficulty concentrating, social isolation, and feelings of hopelessness are also common and impactful (Johns Hopkins Student Assistance Program, 2019). The individual can experience feelings of guilt, worthlessness, hopelessness, pessimism and have difficulty finding happiness in previously enjoyable activities (NIMH, 2017). Other symptoms include slow talking, moving, and decision making, or in extreme cases thoughts of death, suicidal ideation or even suicide attempts. Depressive disorders differ in duration, timing and like many other health concerns depression and how the symptoms manifest is unique to the individual (American Psychiatric Association, 2013; Johns Hopkins Student Assistance Program, 2019; NIMH, 2017).

Major Depressive Disorder (MDD), a recurrent disorder, is characterized by discrete episodes of at least two weeks of clear cognitive and neurovegetative affects that impact function. These episodes may also have inter-episode remissions through the depressive period disorder (American Psychiatric Association, 2013).

Anxiety disorders. Anxiety disorders present in many forms but are mostly characterized by excessive fear and anxiety and related behavioral disturbances (American Psychiatric Association, 2013). Most anxiety disorders are developed in childhood and if not addressed by a medical professional through treatment, can worsen as the individual ages (American Psychiatric

Association, 2013). More females are impacted by anxiety than males by a 2:1 ratio (NIMH, 2017).

General Anxiety Disorder (GAD) is one of the most common anxiety disorders (American Psychiatric Association, 2013). GAD is persistent and excessive anxiety exhibiting worry across domains such as work, education, and social relationships, to name a few. GAD is also accompanied by physical symptoms such as restlessness, becoming easily fatigued, consistently on edge, muscle tension, sleep disturbance, irritability, and difficulty concentrating (American Psychiatric Association, 2013).

Explanations to Rising Mental Illness in College-Aged Young Adults

There are many factors that may explain these increases such as a lack of social support, relationship stressors, or other life challenges (Hunt & Eisenberg, 2010).

Stigma towards mental health. It appears there is a decreased stigma towards mental health issues for current college students as attitudes towards receiving help for mental health are much more favorable in younger adults than in older adults (American Psychiatric Association, 2018; Mojtabai, 2007). Thus, the reports of increasing mental health concerns in college students could be due to the increase of those getting help. However, some other studies suggest that less than half of students who are suffering with a mental health disorder are receiving treatment (Zivin, Eisenberg, Gollust, & Golberstein, 2009).

If less stigma is causing more college students to reach out for help, this may be a cause of increased reporting. Yet, this may also indicate more college students are suffering with mental illness than previously thought. If less stigma is not causing college students to reach for help, then there may be a genuine increase of students impacted by mental illness.

Most people develop mental health disorders as children but tend to not be treated until later. More commonly, it takes years for the patient to seek help, if they search for help at all (Pedrelli et. al., 2015; Prince, 2015). More colleges and universities are providing counseling services and other support systems for students. Some universities are reporting a staggering increase of students now utilizing the student mental health centers (Beiter et. al., 2015).

Traditional College Students and Collegiate Aviation Students

Traditional and non-traditional college students. Traditional college students tend to be around 18-24 years of age. Most enroll directly into a postsecondary institution after completing high school at 18 or 19 years of age (McFarland et. al., 2018; Pedrelli et. al., 2015). Most commonly, these students enroll in 12 or more credit hours of classes and are considered full-time students. Many of these students rely on their parents or other family members for financial support and may also hold a job to supplement the cost of living or their education (Pedrelli et. al., 2015). Many of these students can feel stressed by trying to balance their academics in addition to the new demands of college (Pedrelli et al., 2015).

Non-traditional students are older (above 24 years of age), are usually employed full-time, and may have spouses or dependents (Pedrelli et al., 2015). While these students need to balance their academics with work, and family, they may find more stress in coming back to school and adjusting to the role and expectations of being a student again (Pedrelli et al., 2015).

Collegiate aviation flight students. Collegiate aviation flight students usually maintain the typical college student role while also progressing through the flight portion of their degree program. Aviation flight students are typically full-time students, may maintain full-time or part-time jobs, and are required to spend many hours flying to earn their various flight certificates and ratings. These students may be traditional or non-traditional students.

Flying an aircraft is an inherently stressful activity (Martinussen & Hunter, 2010; Matthews, 2001; Morse & Bor, 2006; Telfer & Biggs, 1988). The pilot's responsibilities include safely operating the plane in a variety of environments, completing periodic check rides, and more. Pilots may experience consistent low-level stress by just being in the airplane. While flying, pilots are constantly monitoring their aircraft and surroundings, which can lead to subtle chronic tension (Suedfeld & Steel, 2000). Additional stress can arise from the requirement to persist in increasing their knowledge and skills as they achieve the designated certificates and ratings for their flight program (Katz, 1997; Matthews, 2001; Salas, Driskell, & Hughes, 1996). A reduction in performance may result in increased number of errors (Martinussen & Hunter, 2010) and accident rates (Loewenthal et al., 2000), as well as the increased financial requirement. Collegiate aviation students are continuously confronted with all these stressors along with those from their academics and everyday life.

Possible Triggers of Mental Health Disorders in College Students

The most common reason found to trigger depression in students are financial issues (Andrews & Wilding, 2004). Financial issues are universal for students, as a post-secondary education has become more expensive possibly leading to a considerable financial burden on the student and their family (Callender & Kemp, 2000). With 70% of high school graduates enrolling in postsecondary education (McFarland et al., 2018), financial burdens on students and families are becoming all the more common (Andrews & Wilding, 2004).

Both anxiety and depression can impact daily life but, depression tends to impact academic performance more than anxiety disorders as the nature of anxiety can motivate students to use compensatory strategies that can increase performance effectiveness (Andrews & Wilding, 2004; Eysenck & Calvo, 1992). Though this sounds like it may be beneficial, often it is not as this can set students up for a lifetime of stress and impact their long-term health and well-being (Stewart-Brown et al., 2000).

Mental Health in Aviation

Mental health in aviation is a sensitive topic and comes with many challenges. Pilots and other flight crew may have a deep aversion to the admittance of a mental health issue as it can put their flight careers in jeopardy. Pilots who are diagnosed with a psychiatric disorder must be grounded until recovered, therefore many may not reach out for help (Bor & Hubbard, 2006;

Morse & Bor, 2006). Additionally, mental health is not a singular topic, as it is diverse, ranges in degree and severity, and can change over time. According to Bor and Hubbard (2006), there are five main sources of mental health problems associated with aviation employees:

> (a) stresses associated with coping, safety, and survival,
> (b) stress that emanates from workload, how work is organized and organizational climate (e.g. rostering, frequency of flights, jet lag, pensions and financial changes),
> (c) personal problems that stem from disruption to personal relationships, which clinical research suggests should act as a buffer to work stress,
> (d) ever-present concerns about loss of license as a consequence of the onset of a disqualifying medical condition, and
> (e) normal psychological problems that occur naturally in the everyday life of the population at large. (p. 2)

Elevated levels of stress can have significant impacts on cognitive processes and decision making. In combination, work and personal stress can impact performance (Blouin et al., 2014). In a survey conducted by Sexton, Thomas, and Helmreich (2000), 74% of pilots reported that stress and fatigue do impact their performance, and 47% reported that personal problems also impact them while flying. If these issues are affecting experienced pilots, there may be similar issues confronting student pilots.

The Federal Aviation Administration (FAA) has specific physical and mental health standards. To receive a First Class Medical, which is required to fly for airlines, pilots must undergo a physical and psychological evaluation (Federal Aviation Administration, 2018a). A First-Class Medical Certificate cannot be issued if the pilot has been diagnosed with a personality disorder, experienced psychosis (hallucinations, delusions, bizarre behavior), bipolar personality disorder, or substance dependence (Federal Aviation Administration, 2018c). Additionally, there are many medications that disqualify or may revoke a pilot's medical due to the potential side effects. Most of the medications used to treat depression and anxiety are included and can cause the pilot to be grounded. Updated in 2010, the FAA has allowed for Special Issuance or Special Consideration to be given to pilots who have been diagnosed with MDD (mild to moderate), Dysthymic Disorder, Adjustment Disorder with depressed mood, and any non-depression related condition where an SSRI (selective serotonin reuptake inhibitor) is used to treat the disorder. There are four medications that can be taken by pilots but are approved on a case by case basis by the FAA (Federal Aviation Administration [FAA], 2018a).

The FAA lists all medications that pilots are and are not able to use while flying. There are two lists: Do Not Issue (DNI) and Do Not Fly (DNF). Any pilot taking any medication on the DNI list will not be issued their flight medical certificate or be able to renew their certificate (FAA, 2018a). Pilots who are taking any medications on the DNF list are highly discouraged to not fly. This list tends to apply more to over-the-counter medications. Pilots are able to return to flying after the medication has been stopped and sufficient time has elapsed allowing the drug to leave the pilot's system.

Pilots are still prone to mental health concerns in spite of extensive medical screening (Morse & Bor, 2006). When the pilot is examined by an Aviation Medical Examiner (AME) the decision to certify the pilot fit for service is up to the AME. AMEs do not diagnose or perform psychiatric exams but make the final decision based on the information provided by the applicant (FAA, 2018a). If the AME cannot make the decision based on the information provided by the applicant, the application is then sent to a FAA certified psychiatrist and all of the pilot's medical records are then reviewed by the FAA (FAA, 2018a).

The ambiguity of the FAA on mental health make it a pain point for many pilots. After physical disorders, psychological disorders, at 12.5% (Pombal, R., Peixoto, H., Lima, M. & Jorge, A., 2005), are the most common reason for pilots to lose their license (Bor & Hubbard, 2006). The loss of a license or even a temporary hold can cause legal, social, and personal consequences.

These rules, regulations, and stigmas do not only apply to the US airline industry, but also includes international pilots. Collegiate aviators may already be in a turbulent and transitional phase of life and with the added stigma and possible consequences of being diagnosed with a mental disorder, these students may be much less likely to reach out for help if it is needed. Even if the student's mental health issue is transient, the student can still be grounded from flight operations impacting the speed at which he/she completes their education. This interruption in training can incite financial concerns as well as complicating other aspects of daily life.

Mental Health and Collegiate Aviation Students

Changes in domestic life, social life, and work may produce stress and other adverse reactions. Internal biological changes can also result in psychiatric disturbances (Morse & Bor, 2006). Academics and personal stresses can create large amounts of stress for students. One of the biggest challenges faced by collegiate aviation students is the cost of flight time. Depending on the certificates and ratings included in the academic program, collegiate flight costs can climb to well above $80,000, for flight time, examiner fees, and supplies (ATP Flight School, 2018).

Financial issues are a contributing factor causing student depression; therefore, the intense costs of an aviation program may put students at a higher risk. Results from a previous study found that 70% of college students are stressed about finances (McDaniel, A., Montalto, C., Ashton, B., Duckett, K., & Croft, A. (2014). This stress can precipitate the onset of mood and anxiety disorders in students (Robinson, Bond & Rosier, 2015). Additionally, previous research focusing on the stress levels of collegiate aviators found that FAA practical tests are the most stressful, followed by financial concerns, written exams, flight course workload, checkride scheduling, and time management (Robertson & Ruiz, 2010).

Pilot Profile

When people think of pilots they may think of a confident and level-headed individual. Some studies even support that there are specific personality types that are drawn to being aviators. The pilot personality as studied by Fitzgibbons, Davis, and Schutte (2004) is quite common. The most common pilot profile is someone who is emotionally stable, has low anxiety, low vulnerability (being able to handle difficult situations), difficult to anger, not impulsive, and low on depression. Pilots are also very contentious, goal-orientated, deliberate, competent and dutiful. Most pilots also are trusting, straightforward, and assertive which helps with crew resource management. Because of this profile and the commonality, a majority of pilots may not have a personality that is prone to mental health problems. This could mean that collegiate aviators could have less anxiety and depression rates.

Purpose of the Study

The purpose of this study was to determine and compare the rates of depression, anxiety, and stress among collegiate flight students and non-professional flight students.

Methodology

This study utilized the DASS-21 (Lovibond & Lovibond, 1995) survey which is comprised of three scales (depression, stress, and anxiety), each with seven Likert-type items utilizing a four-point scale, ranging from Never to Almost Always. The reliability of DASS-21 was confirmed by Antony, Cox, Enns, Bieling and Swinson (1998). Generic, non-identifying demographic questions were also included. The survey used in this study can be found in the Appendix.

The DASS measures features specific to depression, anxiety, and stress. The three sections DASS- D (depression), DASS-S (stress), DASS-A (anxiety) address specific conditions within the DASS. The DASS is a reliable, valid method in both clinical and non-clinical groups (Antony et al., 1998).

This study utilized the DASS-21 for brevity. DASS-21, has fewer items, a cleaner factor structure and a smaller inter-factor correlation. For the purpose of this study the DASS-21 is shorter for students to take, encompasses all of the mental disorders pertinent to the study, and can be compared to previous studies. Additionally, the issue of self-reporting should also be addressed. Respondents were asked to report to the best of their ability. Self-reporting, though beneficial in many cases, can also have issues with over-exaggerated answers, unwillingness of response honestly, and various other biases that may skew reporting reliability. Yet, self-reporting is the main way that clinicians diagnose their patients. The main purpose of this survey is to address whether or not depression, anxiety, or stress, though possibly not diagnosed, is perceived pervasive enough in a respondent’s life that could impact the ability to effectively perform duties asked of them.

After receiving Institutional Review Board approval, the survey was disseminated using convenience sampling. Both paper copies and electronic versions were available for the respondent. The survey was distributed to University Aviation Association (UAA) members via email and at the Women in Aviation (WAI) Conference via iPad. Additionally, the survey was also accessible through a URL with solicitation on social media (Facebook), and in-person requests in college courses with enrollments that included both aviation flight students and non-aviation degree seeking students. Prior to the start of the survey, participants completed a consent form. An additional statement was included to note that due to the nature of the study participants experiencing any discomfort or distress could stop the survey at any time. There was no compensation or class credit available for this study.

Results

Participants

Convenience sampling was used as the respondents took the survey in their classes and included a mix of majors. Of the collected surveys 88% were usable. Of these 224 surveys, 62% were completed by non-collegiate flight students and 38% were completed by collegiate aviation flight students.

Data and Analysis

This study utilized a two-way, mixed factor ANOVA to analyze the data comparing the survey results of collegiate flight students and non-collegiate flight students and comparing of lowerclassmen (freshman and sophomores) and upperclassmen(juniors and seniors).

Summary of Demographics

Table 1
Frequency Distributions of Demographic Characteristics of the Sample

Demographic Characteristic	Category	Frequency	Percent
Class	Freshman	23	10.3
	Sophomore	33	14.7
	Junior	93	41.5
	Senior	59	26.3
	Graduate Student	15	6.7
	Subtotal	223	99.6
	Missing	1	0.4
	Total	224	100
Under/Upper Class	Underclassman	57	25.4
	Upperclassman	167	74.6
	Total	224	100
Gender	Male	144	64.3
	Female	78	34.8
	Other	1	0.4
	Subtotal	223	99.6
	Missing	1	0.4
	Total	224	100
Military Service	Yes	16	7.1
	No	207	92.4
	Subtotal	223	99.6
	Missing	1	0.4
	Total	224	100
Collegiate Flight Student	Yes	87	38.8
	No	137	61.2

Demographic Characteristic	Category	Frequency	Percent
Marital Status	Never Married	210	93.8
	Separated	2	0.9
	Divorced	3	1.3
	Married	9	4
	Total	224	100

The distributions reveal that the participants mainly consisted of upperclassmen (74.6%) and males at (64.3%). The majority of respondents were non-collegiate flight students (61.2%). A large majority of participants were single and had never been married (93.8%) and with a similar occurrence (92.4%) of participants had no current or prior military service.

Psychometric Performance of Dependent Variable Scales

Though the DASS-21 is an established scale and may have exhibited adequate psychometric characteristics in development and in other research studies, its performance with new samples and data may vary quite widely. Particularly with respect to a multi-item scale's internal reliability, if a scale's reliability and performance with the new sample falls below acceptable limit the confidence in the results of its use in the testing of hypotheses may be lost. Thus, it was appropriate and important to address the level of internal reliability that such multi-item scales in the data obtained for this particular study.

To address the internal reliability Cronbach's alpha coefficient was calculated for each of the three scales measuring this study's dependent variables (depression, anxiety, and stress). This assessment is reported in Table 2.

Table 2
Sample-Specific Internal Consistency Reliability Coefficients for the DASS-21

Scale	Cronbach's Alpha	N of Items
Depression	.906	7
Anxiety	.820	7
Stress	.844	7

All three scales revealed alpha coefficients above .80 which was regarded as a sufficient level of internal reliability for this study.

Depression, Anxiety, and Stress

Table 3 depicts descriptive statistics for the dependent variables depression, anxiety, and stress by the categories of the independent variables (upperclassmen, underclassmen).

Table 3
Descriptive Statistics for Depression, Anxiety, and Stress by Collegiate Flight Program and Under- vs. Upper-classman

Dependent Variable		Collegiate Flight Program?						Total
		Yes			No			
		Underclass	Upperclass	Total	Underclass	Upperclass	Total	
Depression	N	35	50	85	19	116	135	220
	Mean	4.78	5.48	5.18	5.05	5.58	5.51	5.38
	SD	3.83	5.12	4.61	4.94	4.95	4.93	4.80
Anxiety	N	37	49	86	19	117	136	222
	Mean	3.86	4.88	4.45	5.26	5.20	5.21	4.91
	SD	3.22	4.62	3.49	4.26	4.18	4.17	3.93
Stress	N	37	47	84	19	113	132	216
	Mean	6.43	7.58	7.09	6.57	6.72	6.71	6.85
	SD	4.11	4.62	4.42	3.83	4.15	4.09	4.22

The three hypotheses were tested using a two-way ANOVA specifying collegiate flight enrollment and under/upperclassman status as the factors for the three dependent variables (depression, anxiety, and stress). To test for compliance with the ANOVA assumption of normality, the residual error terms for each analysis were tested for normality using the Shapiro-Wilk test. Results of this test are shown in Table 4.

Table 4
Results of Normality Tests of the Residual Error Terms of the ANOVAs of Each Dependent Variable

	Shapiro-Wilk		
Error Term	Statistic	df	p
Residual for Depression	.892	212	<.001
Residual for Anxiety	.934	212	<.001
Residual for Stress	.970	212	<.001

The Shapiro-Wilk statistic test is extremely sensitive to sample size. For sample sizes over 60 it is conventional to use the value of the statistic (W) itself as the basis for judging departures from normality. The most common rule used is .90. The residuals for the dependent variables exceeded .90 substantially in two cases and were under .90 by .008 in the one case, it can be concluded that the error terms exhibited have no problematic departure from normality.

Another assumption within ANOVA is homogeneity of variance. This assumption was tested using the Levene test for all three ANOVAs. In all three cases the *p*-values of the Levene test were .09 or higher, indicating that there was no violation of the homogeneity assumption. All hypotheses were tested using the results of the same three ANOVAs (See Tables 5, 6, and 7).

Table 5

Results of ANOVA of Depression by Collegiate Flight Program and Under-/Upperclass Status

Source	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Prof. Flight Program	1	1.967	.021	.885	.000
Under/Upper Classman	1	48.366	.515	.474	.002
Prof. Flight Program * Under/Upper Classman	1	1.118	.012	.913	.000
Error	216	93.987			

R Squared = .003 (Adjusted R Squared = -.010)

Table 6

Results of ANOVA of Anxiety by Collegiate Flight Program and Under-/Upperclass Status

Source	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Prof. Flight Program	1	87.289	1.340	.248	.006
Under/Upper Classman	1	65.048	.998	.319	.005
Prof. Flight Program * Under/Upper Classman	1	32.628	.501	.480	.002
Error	218	65.149			

R Squared = .016 (Adjusted R Squared = .003)

Table 7

Results of ANOVA of Stress by Collegiate Flight Program and Under-/Upperclass Status

Source	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Prof. Flight Program	1	11.030	.146	.703	.001
Under/Upper Classman	1	50.053	.663	.417	.003
Prof. Flight Program * Under/Upper Classman	1	90.966	1.204	.274	.006
Error	212	75.526			

R Squared = .012 (Adjusted R Squared = -.002)

The null hypothesis proposed would be such that there are no specific group of students that are more depressed, stressed, or anxious than the others.

Research question one proposed that students enrolled in a collegiate flight program would have significantly higher levels of depression, anxiety, and stress than non-collegiate flight students. The results for the collegiate flight enrollment factor was not significant in the ANOVAs for all three dependent variables. Thus, it can be concluded that failed to reject the null. This study provides no evidence that supports the existence of higher levels of depression, anxiety, and stress among collegiate flight students compared to non-collegiate flight students.

Research question two proposed that upperclassmen would exhibit significantly higher levels of depression, anxiety and stress than underclassmen. The results for under/upperclassman status factor was nonsignificant in the ANOVAs for all three dependent variables. Thus, it can be concluded that failed to reject the null. This study provides no evidence that supports the existence of higher levels of depression, anxiety, or stress among upperclassmen compared to underclassmen.

Research question three proposed that there is an interaction between upper/underclassmen and the collegiate flight enrollment with depression, anxiety, and stress. The results for the under / upperclassmen status against collegiate flight enrollment interaction was non-significant in the ANOVAs for all three dependent variables. Thus, it is concluded that failed to reject the null. This study provides no evidence that those upperclassmen and underclassmen enrolled in a collegiate flight program have any degrees of difference in depression, anxiety and stress between students enrolled in a collegiate flight program and those not enrolled.

Comparing the averages of the scores to the scoring rubric of the DASS-21 shows that the average of respondents had a normal to mild ranking of depression, anxiety, and stress. Table 8 shows these results. Table 9 shows the scoring rubric for the DASS-21.

Table 8
Score Averages for Depression, Anxiety, and Stress by Collegiate Flight

						Total
Collegiate Flight	*Average Score*	Rank	Non-Collegiate Flight	*Average Score*	Rank	
Stress	7.09	Normal	Stress	6.71	Normal	6.85
Anxiety	4.45	Mild	Anxiety	5.21	Mild	4.91
Depression	5.18	Mild	Depression	5.51	Mild	5.38

Table 9
DASS-21 Scoring Rubric

	Depression	Anxiety	Stress
Normal	0-4	0-3	0-7
Mild	5-6	4-5	8-9
Moderate	7-10	6-7	10-12
Severe	11-13	8-9	19-16
Extremely Severe	14+	10+	17+

Overall, the average scores show that both groups, collegiate flight and non-collegiate flight are both in the mild to normal categories for depression, anxiety, and stress.

Discussion

The purpose of this research was to determine if students who are enrolled in a collegiate aviation flight program are at higher risk for depression, stress, and anxiety than non-flight students, as well as assess whether there are higher depression, anxiety, and stress levels in upperclassmen than in underclassmen. In addition, upperclassmen and underclassmen were compared within collegiate flight programs.

Significant Results

There were no significant results found in this study. Overall, it seems as if students who are enrolled in a collegiate flight program were just as prone to depression, anxiety, and stress as those students who are not enrolled in a collegiate flight program. Additionally, upperclassmen were not more prone to depression, anxiety, or stress compared to underclassmen. An identical result was found when comparing upperclassmen and lowerclassmen enrolled in a collegiate flight program.

A possible explanation for these results is that collegiate flight students are just that; students. Though they incur more academic obligations than non-flight students there are equal opportunities for non-flight students to have equal amounts of responsibilities and additional requirements.

Additionally, as addressed previously, those who are drawn to becoming pilots may have a pilot personality. This personality or at least some personality traits may mean those who are attracted to becoming a pilot may be more resilient and less likely to develop depression, anxiety, or high levels of stress.

Implications

Though there were no significant differences among participant groups, there are still some important findings. Based on this study, no specific group, pilot, non-pilot, upperclassmen, or lower classmen, were more prone to depression, anxiety, or stress than another group. Yet, to assure students are aware of the services available to them, all students still need to be provided education about mental health and have mental health services available to them. Student mental health is a national issue as increases in depression, anxiety, and stress among college have been reported by various organizations.

Collegiate aviation flight students still need to be educated about the impacts that mental health can have on them and their careers. Knowing the signs of common mental health disorders may help them in aiding themselves or others. Positive coping methods and stress relief is an important topic to address for all students.

Overall, this study has shown that there are no specific groups within a collegiate flight program that are more likely to exhibit high statistical levels of depression, anxiety, or stress. Conclusively, students enrolled in a professional flight program are not more or less stressed than those not enrolled in a flight program.

Since these results are positive and the results do not show that either of these student groups are more stressed, depressed, or anxious than others (and actually show a fairly low rate of these traits), it is important to not be lulled into a false sense of security. Though these results are something to be comforted about at these universities and member organizations it is still important to educate all students on the importance of mental health and ways to effectively take care of themselves and produce positive coping mechanisms and self-care strategies.

Limitations & Future Research

This survey was disseminated through email to University Aviation Association institutions, Women in Aviation Conference volunteers, administered during classroom visits, and social media. While a large number of prospective participants had access to the survey, data collection was conducted for three weeks. A longer collection window may have been advantageous to secure more responses from a more diverse sample pool.

Future studies should also take into account other student responsibilities in and outside of the classroom for example, employment status, involvement in student organizations, class credit load, home environment, and other factors. Both collegiate flight and non-flight students have the equal opportunity to incur additional responsibilities in and outside of the classroom. An analysis of pilot personality at the collegiate level may also be a point of interest to future studies. Finally, the same study can be repeated and add a test/re-test aspect. Addressing these limitations may add to a better understanding of collegiate flight students and what is needed to support them.

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APPENDIX

SURVEY INSTRUMENT

Q1 **Please be advised:** All responses to this survey are ANONYMOUS. There will be no way to identify you. These results will be used strictly for research purposes. Please fill out the questions below to the best of your ability. If at any time you do not wish to answer a question or wish to discontinue taking the survey you have the right to do so. Thank you for your time.

Q2 Degree Program

Q3 Estimated date of graduation (Semester, Year):

Q4 Class Standing

Freshman (1), Sophomore (2), Junior (3), Senior (4), Graduate Student (5)

Q5 Are you a transfer student?

Yes (1), No (2)

Q6 Gender

Male (1), Female (2), Other (3)

Q7 Age
Q8 Have you or are you currently serving in the US Armed Forces?

Yes (1), No (2)

Q9 Relationship Status

Never Married (1), Separated (2), Divorced (3), Widowed (4), Married (5)

Q10 Do you have any children?

Yes (1), No (2)

Q11 Are you enrolled in a Collegiate Flight degree program?

Yes (1), No (2)

Skip To: Q13 If Are you enrolled in a Collegiate Flight degree program? = Yes

Skip To: Q16 If Are you enrolled in a Collegiate Flight degree program? = No

Q12 How many flight hours PER WEEK do you have?
Q13 What flight certificates/ratings do you have?

Private Pilot (27), Commercial (28), Instrument (29), Multi-engine (30), CFI (31), CFI-I (32)

Q14 How many total flight hours do you have?
Q15 Are you a pilot (ie: hold any FAA airman certificate or rating)?

Yes (1), No (2)

Q16 If you are not enrolled in a Collegiate Flight major, are you currently taking flight lessons with an FBO or any other type of flight training program?

Yes (1), No (2)

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you over the past week. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:
0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree or a good part of the time
3 Applied to me very much or most of the time

	Never	Sometimes	Often	Almost Always
1. I found it hard to wind down	0	1	2	3
2. I was aware of dryness of my mouth	0	1	2	3
3. I couldn’t seem to experience any positive feeling at all	0	1	2	3
4. I experienced breathing difficulty (e.g. excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5. I found it difficult to work up the initiative to do things	0	1	2	3
6. I tended to over-react to situations	0	1	2	3
7. I experienced trembling (e.g. in the hands)	0	1	2	3
8. I felt that I was using a lot of nervous energy	0	1	2	3
9. I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
10. I felt that I had nothing to look forward to	0	1	2	3
11. I found myself getting agitated	0	1	2	3
12. I found it difficult to relax	0	1	2	3
13. I felt down-hearted and blue	0	1	2	3
14. I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
15. I felt I was close to panic	0	1	2	3
16. I was unable to become enthusiastic about anything	0	1	2	3
17. I felt I wasn’t worth much as a person	0	1	2	3
18. I felt that I was rather touchy	0	1	2	3
19. I was aware of the action of my heart in the absences of physical exertion (e.g. sense of heart rate increase, heart missing a beat)	0	1	2	3
20. I felt scared without any good reason	0	1	2	3
21. I felt that life was meaningless	0	1	2	3

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How Weather, Terrain, Flight Time, and Population Density Affect Consumer Willingness to Fly in Autonomous Air Taxis

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Background: Many studies have investigated passengers' willingness to fly (WTF) or ride in autonomous aircraft and vehicles. With the emergence of urban air mobility, it is important to consider consumer perceptions of autonomous air taxis and passengers' willingness to fly in various conditions. Therefore, the purpose of this study was to determine what external factors may influence consumers' willingness to fly on autonomous air taxis in various weather conditions, terrain, flight time, and population densities. Methods: Across two studies, 782 participants were presented with a definition of autonomous air taxis. Then a hypothetical scenario involving an air taxi that included four variables: rain versus no rain (Weather), 5-minute flight versus 30-minute flight (Flight Time), over land or water (Terrain), and over urban or rural areas (Population Density). Results: The data from the study suggest that both United States and Indian passengers were more willing to fly in good weather conditions versus rainy weather, over land versus over water, and on short flights versus longer flights. Conclusions: As urban air mobility becomes more well-known, it is important to understand consumer opinions and educate them on emerging technology. This, in turn, can aid industries in developing marketing strategies to help increase awareness of new technologies in the future.

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Ragbir, N.K., Rice, S., Winter, S.R., Choy, E.C., & Milner, M.N. (2020). How Weather, Terrain, Flight Time, and Population Density Affect Consumer Willingness to Fly in Autonomous Air Taxis. *Collegiate Aviation Review International*, 38(1), 69-87. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/7962/7350

Prior research has extensively examined consumers' perceptions and how certain perceptions can influence their willingness to fly in autonomous vehicles (Asgari & Jin, 2019; Haddad, Chaniotakis, Straubinger, Plötner, & Antoniou, 2020; Hughes, Rice, Trafimow, & Clayton, 2009; Mehta, Rice, & Winter, 2014; Mehta, Rice, Winter, & Eudy, 2017; Ragbir, Baugh, Rice, & Winter, 2018; Rice, Kraemer,Winter, Mehta, & Dunbar, 2014; Rice, Winter, Mehta, & Ragbir, 2019; Rice & Winter, 2015). However, research on external factors and their impact on the adoption of autonomous vehicles for urban air mobility (UAM) is limited. Traffic congestion on the ground can be extremely high in many urban areas, and there is a lot of airspaces available to alleviate this congestion. Since transportation is most effective when it can assist the masses, it is important to know in what conditions consumers are most likely to adopt and use UAM. Thus, the purpose of this study aims to determine consumers' willingness to fly in autonomous air taxis in varying weather, flight time, terrain, and population density conditions. This study will also consider consumers' cultural differences between India and the United States and how that may affect individual responses to the adoption and use of UAM in varying conditions.

Urban Air Mobility

Urban air mobility (UAM) refers to transportation systems, mainly within urban areas, that move people by air (Thipphavong et al., 2018). This system is intended to reduce traffic congestion by creating more avenues for public transportation. There are various barriers to the successful implementation of UAM. First, the technology and infrastructure need to be reliable and accessible to the public (Risen, 2018). For example, for an electric vehicle with vertical takeoff and landing (VTOL), like a helicopter, to provide transportation in urban areas, it needs to have a robust battery and designated landing pads. Another important barrier is the expense as emerging technology and infrastructure are quite costly throughout the developmental process (Risen, 2018). Therefore, it is imperative to optimize costs while upholding safety to create a transportation system that can truly assist the public and reduce congestion.

Another important barrier to consider is the public's likelihood of adoption of UAM. Haddad et al. (2020) studied factors that can affect adoption, like the 1989 Technology Acceptance Model by Davis, Bagozzi, and Warshaw. The results indicated that the key factors associated with the adoption are safety, trip cost, trip duration, and service reliability. Analyses of socio-demographic factors indicated that females were much less interested in UAM adoption by expressing lower trust, lower perceived usefulness, and greater concerns for safety and security (Haddad et al., 2020). Tackling these barriers is key for future researchers and designers, as resolving them could lead to a higher potential for UAM adoption. While technology is advancing for all autonomous vehicles, it is ideal that autonomous cars are available to the masses first as this adoption and growing familiarity will assist with autonomous aircraft in the future.

Moreover, Unmanned Aerial Systems, or better known as drones, also play a role in understanding the public's adoption of autonomous technology. Drones do not have a human pilot onboard; however, a pilot is operating the aircraft by remote control (Clothier, Greer, Greer, & Mehta, 2015). As drones began to gain popularity, some citizens expressed apprehensions regarding drone operations. One study explored a predictive approach to understand what factors predicted an individual's privacy concerns of drones (Marte et al., 2018). The results of the study suggested that seven factors predicted these concerns, some of which was the importance of privacy, attitudes towards drones, and safety in the neighborhood (Marte et al., 2018). The Federal Aviation Administration issued new regulations beginning in 2020 regarding recreational drone flying in the U.S. Some regulations include flying below 400 feet, not flying in controlled airspaces such as around airports, and no flying in airspaces where a flight is prohibited (Federal Aviation Administration [FAA], 2020).

Cultural Considerations

The study of human behavior is complex because there are so many variables and influences involved. This study strives to further understand human behavior and decision-making by accounting for nationality and perceptions of various flight conditions. Determining how nationality can play a role typically involves cultural influences. Culture is difficult to define because its influences on society and individuals are mostly invisible (Hofstede, 1984). Helmreich defines culture as "shared norms, values, and practices associated with a nation, organization, or profession" (2000, p. 134). It is extremely important to consider cultural differences across nations because of the limits to generalizability. What may be common practice or belief in one culture may even be unheard of in another culture. For example, an individual's willingness to trust others may be influenced by cultural background, and therefore, cannot be generalized to individuals that do not share a similar culture (Hofstede, 1980).

In this study, the participants were either from the United States or Indian. Participants from both countries are important to the aviation market because millions fly each year in India and close to a billion fly in the United States (Carrerio, n.d.; Bureau of Transportation Statistics, 2019). One key cultural difference between these nations is the value of individualism in the United States versus collectivism in India. Markus and Kitayama (1991) concluded that collectivist cultures have an interdependent view of the self. Individuals are taught to trust without question and to take others' interests into higher regard than their own (Wu & Jang, 2008; Rice et al., 2014). Collectivist cultures also have a preference for a closely-knit social framework, where individuals can rely on nurturing from relatives and others within the in-group in exchange for unquestioning loyalty (Hofstede, 1980).

Conversely, individualistic cultures place preference for a more relaxed social framework, where individuals care for themselves and their immediate families only (Hofstede, 1980, 1984). Those of individualistic cultures are also more autonomous and independent from their in-groups, as they prioritize personal goals over group goals (Triandis, 2002). It is common for individualists to behave based on their attitudes, as opposed to aligning behaviors to mimic those of the in-groups.

To further solidify the cultural differences between India and the United States, on Hofstede’s Cultural Values by Nation Index comparing individualistic and collectivist dimensions, India scored a 48 out of 100. This score indicates that culture is mainly collectivist with some individualistic characteristics (Hofstede, 1980, 1984). The United States scored the highest value at 91 out of 100, which suggests a strong individualistic culture. For this study, the differences in cultures will play a role in the participant’s willingness to fly in autonomous vehicles.

Willingness to Fly on Autonomous Aircraft

Automation is the capability for technology to select data, transform information, make decisions, and control processes (Hughes et al., 2009). To improve human performance, automation is commonly utilized in the field of aviation, which includes aircraft take off, piloting, and landing. An autonomous aircraft does not require a pilot and can fulfill all operation procedures required to fly an aircraft safely such as interaction with air traffic controllers and national airspace (Ragbir et al., 2018). On the other hand, drones or unmanned aerial systems are operated by a pilot who is controlling the aircraft through a remote control device, though one similarity between autonomous aircrafts and drones is there is no human pilot directly onboard the aircraft.

However, the successful adoption of automation in commercial aircraft relies heavily on consumer opinions. These opinions pertained to risk, knowledge, price, trust, and reliability (Hughes et al., 2009). Pilots must be comfortable working with associated risks and be knowledgeable with more complex technologies should problems arise. Passengers prefer that the price is affordable, but not so inexpensive that quality is compromised. Lastly, both pilots and passengers need to be able to trust the automation to work reliably. While these opinions may seem reasonable and workable, it is not uncommon for individuals to exercise the *affect heuristic*, which is unconsciously and immediately assessing an object as good or bad based on feeling, regardless of actual risk or benefit (Hughes et al., 2009). In a 2009 study by Hughes and colleagues, participants almost always preferred the human pilot over the automated pilot, both functioning at 99% reliability when accounting for the price, trust, confidence and emergency. Therefore, it is likely that automation technology needs to overachieve in commonly used areas to combat negative affect heuristic and improve consumer opinions.

In addition to ensuring overachievement, it is important to develop familiarity either by interactions, experiences, or pure learning because trust is developed “within the set of familiarity” (Mehta, Rice, & Winter, 2014). For example, consumers are very trusting in the use of cruise control because they are familiar with the functional parameters from experience. In a 2014 study by Mehta and colleagues, participants, varying from novice to expert in aviation, ranked their familiarity and reliability with numerous automated aircraft devices (e.g., airspeed indicator, autopilot, anti-ice controls, etc.). The results indicated a strong correlation between familiarity with device and perceived reliability (Mehta et al., 2014). Even though the average consumer will have minimal aviation experience, it is worth developing familiarity through in-flight pamphlets and other learning materials. Repeated exposure will help consumers develop more trust in automation.

When striving towards more exposure and familiarity, it is important to know the consumer, as well, and be able to account for cultural norms. In a 2014 study by Rice and colleagues, results indicated that Indians and participants from the U.S. were more comfortable, trusting, and willing to fly with a human pilot than an automated aircraft. However, Indian participants were more forgiving when it came to automated and remote-controlled (RC) aircrafts in comfort, trust, and willingness than American participants (Rice et al., 2014). These results are further supported in a study by Ragbir et al. (2018) where willingness to fly in an autonomous aircraft accounted for nationality, weather, wind, and distance. Across the board, Indians were much more willing to fly in an autonomous aircraft, as almost every American participant responded negatively across all conditions. These results are likely due to differences in societal norms rooted in collectivism or individualism of Indians and Americans, respectively. It is uncommon within collective cultures, like Indians, to challenge the status quo or push boundaries. Therefore, to conform with others, Indian participants are likely to be moderates, as opposed to extremists.

Winter et al. (2015) expanded on the research by focusing on cockpit configurations (e.g., one or two pilots onboard and/or one or two pilots in a remote-control ground station with no autonomy). Both Indian and participants from the U.S preferred having a traditional cockpit, where both pilots are onboard. However, both groups of participants were slightly more in favor of the aircraft that were operated by remote-control to delivered cargo, as opposed to passengers (Winter et al., 2015). While the preference was not significant, this could be a starting point to teach the usefulness and reliability of automation in aviation. In 2017, a study by Mehta and colleagues expanded on cockpit configurations to account for gender. Indian male participants were less willing to fly when two female pilots were onboard, but still preferred all human pilot configurations over autopilot. Even though Indian participants are generally more in favor of automation in aviation than Americans, it is still important to properly familiarize Indians and Americans with the technology, likely with different learning methodologies, so that they are informed consumers.

While there may be cultural perspective differences in the use of automation in aviation, there are emotions that are more congruent across all individuals and less dependent on culture. In 2015, Rice and Winter conducted a study utilizing emotions as a mediator for pilot configurations and the willingness to fly. All participants in the study experienced more negatively associated emotions when presented with autopilot configurations, including anger, disgust, fear, sadness, and surprise. The only clear positive emotion, happiness, was expressed significantly in favor of human pilots. There was also a correlation between emotions and the willingness to fly. Participants that expressed a negative affect for autopilot were not willing to fly, whereas participants that had expressed a positive affect for human pilots were also more willing to fly (Rice & Winter, 2015). These correlated emotions are also consistent with Rice, Winter, Deaton, and Cremer (2016) regarding system-wide trust (SWT) loss. Participants that were more likely to feel negative about aircraft automation failures (e.g., unnecessary deployed oxygen masks) also lost trust in the other automated systems that did not fail (e.g., autopilot system, landing gear, seat video monitor). While SWT loss and negative perceptions are likely to be consistently correlated, it is important to address and reassure consumers that not all components within the aircraft are entirely linked or interconnected. As mentioned previously, familiarity and experience with autonomous aviation and its processes can assist with building and earning trust.

While there may be disparities in willingness to fly in autonomous aircraft, consumers do acknowledge the advantages, as well. In the qualitative portion of Ragbir and colleague’s (2018) study, participants mentioned that autonomous aircrafts would have *less human error* as there are *no emotions involved*. Participants also mentioned that the autopilot would not fatigue like a human pilot, and there may be *cheaper flight costs* (Ragbir et al., 2018). Individuals who buy into the advantages of autonomous aircrafts would likely be more willing to fly in the future. Rice et al. (2019) conducted a study to determine if there are predictors of individuals who are more willing to fly and may be early adopters to the technology. The seven significant predictors were familiarity, fun factor, wariness of new technology, fear, happiness, age, and education level. It is reasonable that individuals with more knowledge in aviation and autonomous technology are more willing to fly as the opportunities become available. Those same individuals may feel happiness or perceive emerging technology as fun since they have a better idea of how aircraft worked traditionally (Rice et al., 2019). It is important not only to identify these individuals that are more likely to support and be willing to fly in autonomous aircraft but also to consider their input on improvements to better the technology for the masses.

Willingness to Ride in Autonomous Cars

Similar to aviation, autonomous technology intends to reduce human error and fatigue when in an automotive vehicle. However, differing media portrayals can have an impact on the potential consumers’ perspectives on willingness to ride. Anania et al. (2018) conducted a study determining the effects of information regarding driverless vehicles and whether nationality or gender can affect the consumer’s willingness to ride. Firstly, there were correlations where individuals were more willing to ride after hearing positive information and less willing to ride after hearing negative information. These results made clear the importance of seeking information from various sources to get a better understanding of the technology and a more accurate perspective of advantages and disadvantages to autonomous cars. Similar to findings within autonomous aircraft, Indian participants were also more willing to ride in driverless cars than American participants. Gender had less consistent correlations as Indian females reported the highest willingness to ride scores, but American females reported the lowest willingness to ride scores (Anania et al., 2018).

Further research by Rice and Winter (2019) demonstrated that females were less willing to ride compared to males, and that effect was mostly mediated by fear and anger. These emotional responses may be due to perceptions of complexity in the technology, a lack of fun factor, and less familiarity with technology. The study results also demonstrated a significant effect for age, where older participants were less willing to ride compared to younger participants. These results supported previous findings by Winter and colleagues in 2018. They had applied an affective perspective to consumer use of driverless ambulances. Both genders preferred having a human as the driver of an emergency medical service vehicle (Winter et al., 2018). Similar to results by Rice and Winter (2019), females were less willing to ride in driverless ambulances, and this result was mostly mediated by anger.

Similar to literature from autonomous aircraft, there will always be consumers that are not willing to ride in driverless cars. However, as technology continues to advance and become more accessible, it is important to identify those who are willing to ride and become early adopters. A study by Asgari and Jin (2019) utilized attitudinal factors as mediators for consumers who are willing to adopt or pay for autonomous vehicles. The four most prominent factors were the *joy of driving*, *mode choice reasoning*, *trust*, and *technology savviness* (Asgari & Jin, 2019). Participants that enjoyed driving were less willing to adopt and pay for autonomous vehicles. However, participants that were technologically savvy were much more willing to adopt the use of autonomous vehicles. *Mode choice reasoning* referred to individuals that factored in the costs and benefits of a driverless vehicle, and were only willing to pay for automated features if it would save time and cost, be more convenient, reduce stress, improve quality of life, or produce some other benefit (Asgari & Jin, 2019). Lastly, individuals with low trust were more likely to pay for automated features as they would provide more privacy and protection compared to public transit or other shared mobility options (Asgari & Jin, 2019). Knowing where consumers are hesitant or excited about autonomous vehicles is one of the best courses of action toward developing technology that can be utilized by the masses.

Current Study

Prior research has shown that consumers are more willing to fly in vehicles that are manned by humans versus fully autonomous vehicles (Anania et al., 2018; Hughes et al., 2009; Mehta et al., 2014; Rice et al., 2014; Rice et al., 2019; Rice & Winter, 2015; Winter et al., 2015). However, there are emerging consumers that are willing to be early adopters of autonomous vehicles, and they share similar interests and factors. Indian consumers tend to be more willing to fly or ride on autonomous vehicles than American consumers (Rice et al., 2014). Familiarity with technology and emotions are also mediators for consumers interested and willing to fly or ride in autonomous aircraft or vehicles (Mehta et al., 2014; Rice & Winter, 2015; Rice & Winter, 2019). This study will expand on previous research by determining which external factors may affect consumers in their willingness to fly in an autonomous aircraft designed for UAM in various weather, flight time, and environmental conditions. The following research question drove this study:

> RQ: Do weather, terrain, flight time, and population density affect consumer willingness to fly in autonomous air taxis?
>
> We hypothesized the following:
>
> Ha1: Participants would be more willing to fly in an air taxi in good weather versus rainy weather.
> Ha2: Participants would be more willing to fly in an air taxi over dry land versus over water.
> Ha3: Participants would be more willing to fly in an air taxi for shorter flights versus longer flights.
> Ha4: Participants would be more willing to fly in an air taxi over rural areas versus urban areas.

Study 1 – Methods

Study 1 investigated which external factors may affect consumers in their willingness to fly in an autonomous aircraft designed for UAM in various weather, flight time, and environmental conditions. Study 1 used American participants only. Both studies utilized a within-participants experimental design where all participants were responding to all conditions. Each participant was presented with a randomly ordered set of scenarios to avoid order effects.

Participants

Four hundred and ninety-six (261 females) people took part in the study. All participants were located in the United States. The mean age was 37.77 years old (*SD* = 11.54). Participants were recruited from Amazon's Mechanical Turk, which is an online portal where participants receive monetary compensation for completing human intelligence tasks. Data from this site have been shown to have high reliability, similar to what is found in experimental labs (Buhrmester, Kwang, & Gosling, 2011; Germine et al., 2012; Rice, Winter, Doherty & Milner, 2017).

Materials and Stimuli and Procedure

Participants first read and signed an electronic informed consent, and then, they were given instructions. Participants were presented with a definition of autonomous air taxis, and followed by a hypothetical scenario involving an air taxi. Specifically, they were told:

> *Imagine a situation where you have no other option of getting across a major city except to ride in an autonomous air taxi. This aircraft has no human pilot and is fully automated. There are no flight controls, and no way for anyone inside to take over control.*

Afterward, they were asked how willing or unwilling they would be to ride in the air taxi under a variety of conditions that were divided into four experimental independent variables: rain versus no rain (Weather), 5-minute flight versus 30-minute flight (Flight Time), over land or water (Terrain), and over urban or rural terrain (Population Density). Each of these conditions was crossed with all other conditions for a total of 16 conditions. Participants responded to the *willingness to fly scale* (WTF) (Rice et al., 2020) with seven possible responses from extremely unwilling to fly (-3) to extremely willing to fly (+3) with a zero neutral option. A description of the scale can be found in Appendix A.

They were then asked basic demographics questions and allowed to elaborate, if they wished, with open-ended questions. Finally, participants were debriefed, compensated, and dismissed.

Ethics

This research followed the ethical protocol for human participants' research with oversight from the Institutional Review Board. All researchers have current CITI certificates, and all participants were provided with consent forms.

Study 1 – Results

Figures 1 and 2 present the results from Study 1 for both the 30-minute flight time and the 5-minute flight time. A four-way analysis of variance using Weather, Flight Time, Terrain and PopDensity as the main factors revealed significant main effects of Weather, *F*(1, 468) = 148.24, p < .001, *partial eta-squared* = .24, of Flight Time, *F*(1, 468) = 148.46, *p* < .001, *partial eta-squared* = .24, and of Terrain, *F*(1, 468) = 46.31, *p* < .001, *partial eta-squared* = .09. There was a significant interaction between Weather and Terrain, *F*(1, 468) = 4.01, *p* = .046, *partial eta-squared* = .01. There was no significant interactions between Urban and Rural (PopDensity) areas *F*(1, 468) = 0.45, *p* = .502, *partial eta-squared* = .001.

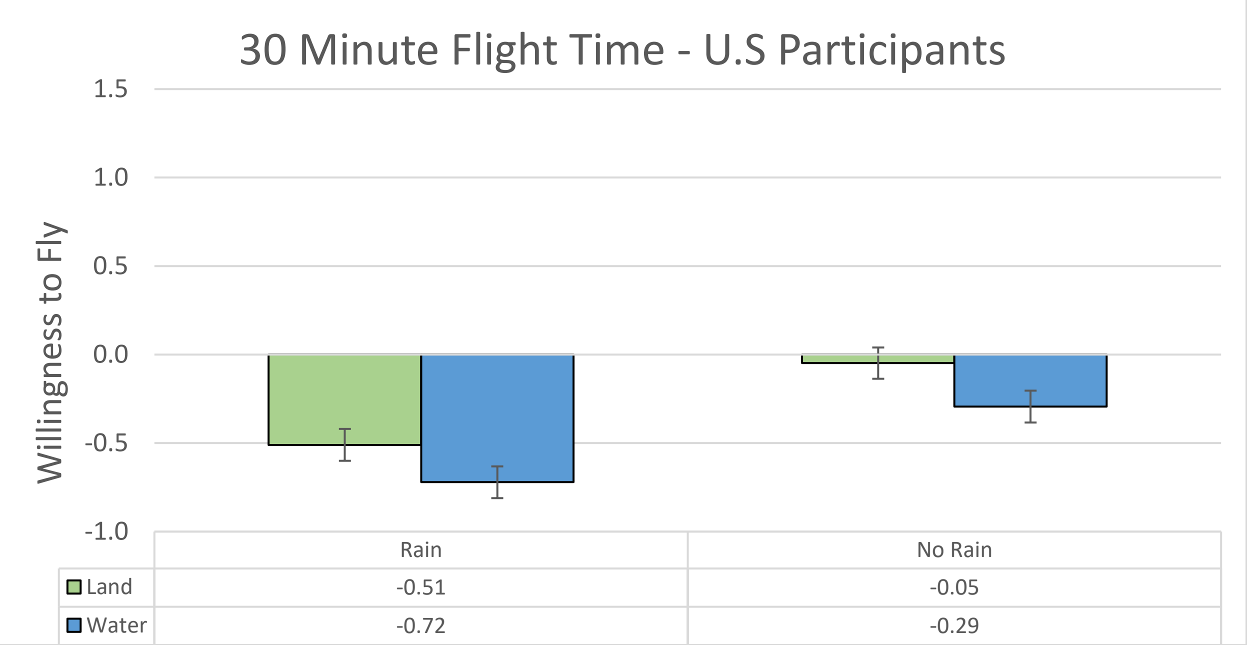


Figure 1. United States participant data on the 30 minute flight time. Standard error bars are included.

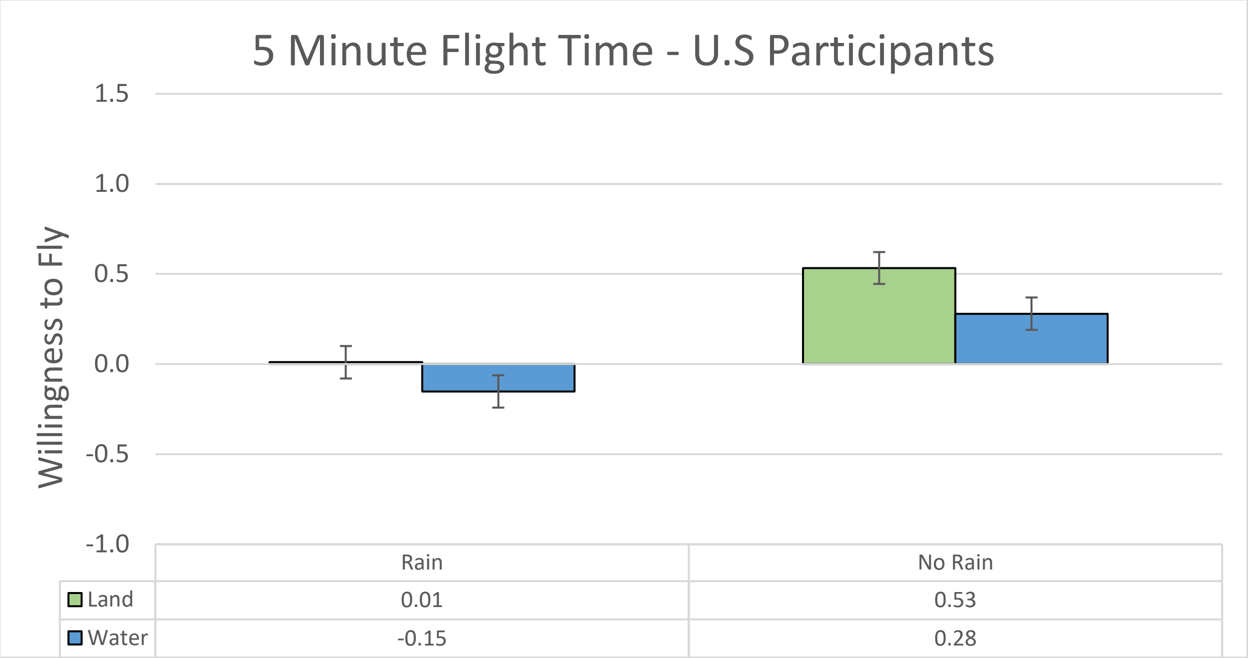


Figure 2. United States participant data on the five minute flight time. Standard error bars are included.

Study 1 – Discussion

Participants were more willing to fly in the air taxi when the weather was clear, if the flight was short, and if they were flying over dry land. The data revealed no significant differences between flying over urban or rural areas. There was a weather by terrain interaction, but it was barely significant, and the graphs do not reveal a practical interaction that is necessary to discuss in detail.

Study 2 – Introduction

Study 1 revealed that participants were more willing to fly in certain situations. Specifically, this included very short flights, in good weather, and over land. However, it has been well documented that Americans tend to be more negative about using advanced technologies compared to their Indian counterparts (Mehta et al., 2017; Ragbir et al., 2018; Rice et al., 2019). The purpose of Study 2 was to replicate the findings from Study 1 using a sample from India. We hypothesized the following:

Ha1: Participants would be more willing to fly in an air taxi in good weather versus rainy weather.
Ha2: Participants would be more willing to fly in an air taxi over dry land versus over water.
Ha3: Participants would be more willing to fly in an air taxi for shorter flights versus longer flights.
Ha4: Participants would be more willing to fly in an air taxi over rural areas versus urban areas.

Study 2 – Methods

Participants

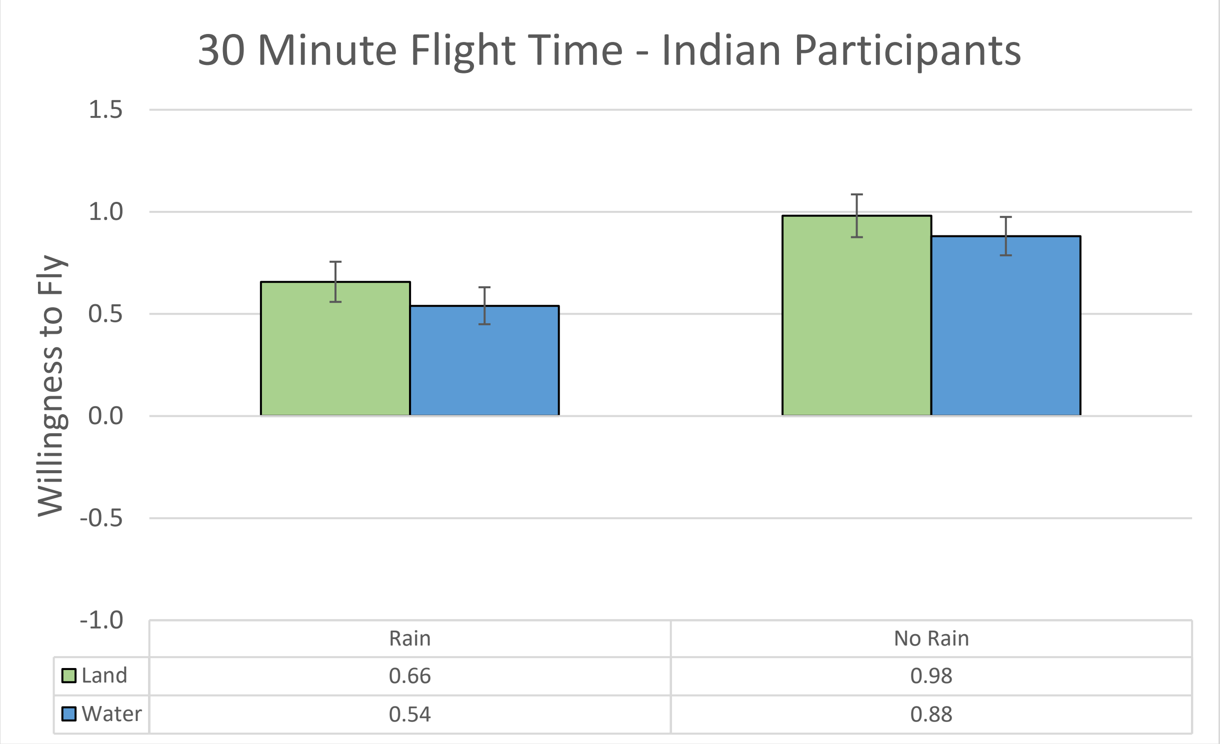
Two hundred and eighty-six (73 females) people took part in this study. All participants were located in India. The mean age was 31.29 (*SD* = 7.45). Participants were again recruited from Amazon's Mechanical Turk.

Materials and Stimuli and Procedure

Study 2 was identical to Study 1 with one exception: participants were located in India rather than from the United States.

Study 2 – Results

Figures 3 and 4 present the results from Study 2 for both the 30-minute flight time and the 5-minute flight time. A four-way analysis of variance using Weather, Flight Time, Terrain and PopDensity as the main factors revealed significant main effects of Weather, *F*(1, 262) = 27.13, *p* < .001, *partial eta-squared* = .09, of Flight Time, *F*(1, 262) = 30.92, *p* < .001, *partial eta-squared* = .11, and of Terrain, *F*(1, 262) = 10.63, *p* = .001, *partial eta-squared* = .04. There was no significant interactions between Urban and Rural (PopDensity) areas *F*(1, 262) = .383, *p* = .537, *partial eta-squared* = .001.



	Rain	No Rain
🟩 Land	0.66	0.98
🟦 Water	0.54	0.88

Figure 3. Indian participant data on the 30 minute flight time. Standard error bars are included.

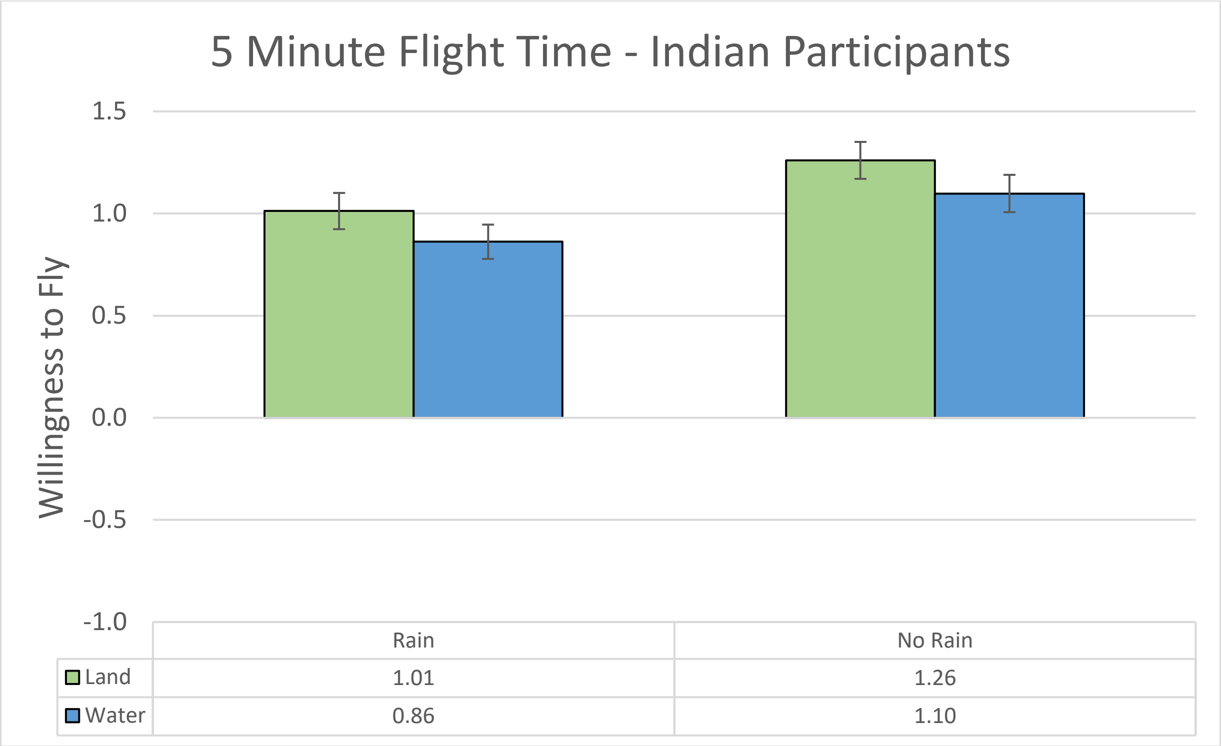


Figure 4. Indian participant data on the five minute flight time. Standard error bars are included.

Study 2 – Discussion

The data from Study 2 are both similar and different from Study 1. Replicating Study 1, participants were more willing to fly in the air taxi when the weather was clear if the flight was short, and if they were flying over dry land. However, when comparing the data from Figures 3 and 4 to Figures 1 and 2, Indians reported much higher WTF ratings compared to their American counterparts. This phenomenon has been seen in previous studies about willingness to use advanced technologies, and we discuss this in more detail in the General Discussion.

General Discussion

Many studies have investigated passengers' willingness to fly or ride in autonomous aircraft and vehicles (Anania et al., 2018; Ragbir et al., 2018; Rice et al., 2014; Rice & Winter, 2019; Vance & Malik, 2015). Though, with the emergence of urban air mobility, it is important to consider consumer perceptions of autonomous air taxis and passengers' WTF in various conditions. Therefore, the purpose of this study was to determine what external factors may influence consumers' WTF on autonomous air taxis in various weather, flight time, terrain, and population density conditions.

The authors first hypothesized that participants would be more willing to fly in an air taxi in good weather compared to rainy weather. The data from both studies supported this hypothesis. In study 1, American participants were less willing to fly in inclement weather. Similarly, in the second study, Indian participants were also less willing to fly in the rain. Chen, Zhao, Liu, Ren, and Liu (2019) investigated how a driver's perceived risk changed while driving a car under different adverse weather conditions by using a driving simulation. The authors highlighted that a driver's perceived risk was highest during rainy and heavy fog conditions. This uncertainty of risk could potentially transfer to aircraft, as well as autonomous systems. Another recent study found that both participants from the U.S and India were less willing to fly in autonomous aircraft if it was raining. The results also showed a significant difference in Indian participants displaying a more willingness to fly in autonomous aircrafts overall (Ragbir et al., 2018).

The second hypothesis stated that participants would be more willing to fly in an air taxi for short amounts of time compared to long amounts of time. The data from both studies supported the hypothesis. In study 1, Americans participants were more willing to fly in the autonomous air taxi for five minutes as opposed to 30 minutes. In study 2, Indian participants displayed analogous results, illustrating more positivity towards flying for five minutes in the air taxi rather than 30 minutes. One possibility for these results could be the consumers' familiarity with the development of urban air mobility, and in turn, autonomous air taxis. Passengers can have the perception that the longer lengths of time traveling in new modes of transportation could offer more possibilities for issues.

The third hypothesis stated that participants would be more willing to fly in an air taxi over dry land compared to over water. The data from both studies supported this hypothesis. In study 1, American participants were more willing to fly over land than water. In study 2, Indian participants reflected the same attitudes. Perhaps, participants felt flying over water would result in the additional danger of drowning if the vehicle was unable to land safely. Another possible reason for these results could be access to emergency response resources if a vehicle were to go down on land as opposed to water.

The final hypothesis stated that participants would be more willing to fly in an air taxi over rural areas compared to over urban areas. The data from both studies showed that population density was not a factor. In study 1, there was no significant difference between flying over rural or urban areas for American participates. Similarly, in study 2, there was no significant difference in population densities for Indian participants.

Lastly, we note that there may be some differences between Indians and Americans. Prior research has shown that Indians tend to be more accepting of new technologies compared to their American counterparts, and this data certainly does not dispel that notion. However, the authors did not conduct statistical analyses on these differences because they are not confident that they have captured identical samples from each country that would be conducive to making this comparison. The participants from the United States are probably closer to the average American, while the participants from India are probably more educated and wealthy than the average Indian. Having access to the internet and being able to work online via MTurk is probably more of a luxury reserved for the higher class in India. Thus, we worry that we might be comparing a smaller subset of the Indian population to a more general subset of United States participants.

Practical Applications

The findings from the study provide some meaningful, practical applications, especially as aerial taxi manufacturers and companies continue extensive development of vehicles intending to deploy urban air mobility devices within the next few years. First, the data indicate that passengers are more willing to fly when the weather is good. This finding is important, but it also presents some challenges. While the finding that passengers are more willing to fly in good weather is perhaps intuitive, for air taxi operations to be successful, there will likely need to maintain a level of reliability equal to or better than traditional ground-based vehicle, such as a car. If aerial taxi flights have to cancel frequently for the weather, this could deter passengers from seeking to use this service.

Another practical outcome of the study relates to the routing of flights. Passengers indicated greater willingness to be over dry land as opposed to water. This factor could present some challenges, as some initial discussions related to urban air mobility routings have considered taking flights over waterways to avoid the congestion of downtown metropolitan areas as well as noise abatement concerns. While passengers may be willing to fly over lakes or ponds, flights over extended waterways may be a deterrent to some passengers. As a result, operators should give consideration not only to the most logical flight path routings of these initial flights, but also the concerns of the passengers who will be flying onboard.

Limitations

Some limitations bound the current studies. First, a convenience sample was used, which provides restrictions on the generalizability of the findings. The sample was drawn from an online repository of participants, Amazon’s MTurk, and it was limited to only two countries. Data for the study was conducted cross-sectionally so the findings indicate consumer preference at one point in time. As additional testing continues and becomes more common, it is possible, and likely, that consumers’ views will shift based on the outcomes of these trials.

Conclusion

The purpose of this study was to determine what external factors may influence consumers’ WTF on autonomous air taxis in various weather, flight time, terrain, and population density conditions. The data from the study suggested that both American and Indian passengers were more willing to fly in good weather conditions (i.e., no rain, no wind), over land, and on short flights consisting of about five minutes. The results of the study also suggest that Indian and American participants were not concerned if they were flying over rural or urban areas. As urban air mobility becomes more well-known, with several years of a solid safety record, it could be possible that passengers may become more willing to fly in adverse conditions. These results are valuable in understanding how to reach consumers and educate them on emerging technology. This, in turn, can aid industries in developing marketing strategies to help increase awareness of new technologies in the future.

Future Research

As revealed, several studies have explored differences between participants from the United States and India and their willingness to fly in autonomous aircraft. Prior research has also captured their attitudes regarding new technology. Future studies should identify whether these differences are reflected in autonomous air taxis as well. Other studies could potentially investigate whether age, income, and residence influence the results from participants in the U.S. Also, many countries have expressed an interest or are actively engaging in urban air mobility testing, future research should expand the sample from this study to see if the findings replicate across broader populations. Therefore, conducting frequent replication studies over time will provide valuable insights into the trends of consumer willingness to fly onboard urban air mobility devices.

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Appendix A – Willingness to Fly Scale (Rice et al., 2015; Rice et al., 2020)

1) I would be happy to fly in this situation

Strongly Disagree Disagree NeutralAgree Strongly Agree

2) I would be willing to fly in this situation

Strongly Disagree Disagree NeutralAgree Strongly Agree

3) I have no fears of flying in this situation

Strongly Disagree Disagree NeutralAgree Strongly Agree

4) I would be comfortable flying in this situation

Strongly Disagree Disagree NeutralAgree Strongly Agree

5) I would have no problem flying in this situation

Strongly Disagree Disagree NeutralAgree Strongly Agree

6) I feel confident flying in this situation

Strongly Disagree Disagree NeutralAgree Strongly Agree

7) I would feel safe flying in this situation

Strongly Disagree Disagree NeutralAgree Strongly Agree

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Further Improving General Aviation Flight Safety: Analysis of Aircraft Accidents During Takeoff

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Data from the National Transportation Safety Board (NTSB) reveal that general aviation (GA) accounted for 76% of total air transport related accidents and incidents in the U.S. between 2014 and 2019. The identification of causes is one of the most important tasks in aircraft accident investigation and a critical strategy for proactive aircraft accident prevention. Aircraft and flight crew perform differently in each phase of flight given the changes of aircraft configuration, flight operation environment and flight crew workload, therefore, the causes of aircraft accident may vary by phase of flight. Most accidents occur in the phases of final approach and landing have been investigated by many researchers from various perspectives. Few studies, however, have been published on flight safety for the phase of takeoff, which has the second-highest number of GA aircraft accidents and incidents. A good understanding of the causes of GA aircraft accidents during takeoff is crucial to develop more effective countermeasures for aircraft takeoff risk mitigation and accident prevention. The objective of this study is to understand the causes of GA aircraft takeoff accidents by analyzing aircraft accident investigation reports published by the NTSB. To better understand the causes of GA aircraft takeoff accidents, the following research design has been implemented. First, comparative analysis was applied to depict the statistical features of GA takeoff accidents compared to other air transport categories. Temporal change of GA takeoff accidents was analyzed using a linear-by-linear association test. Secondly, primary accident causes were identified by analyzing the NTSB investigation reports. Text mining techniques were applied to further explore contributing factors associated with the identified causes to enrich discovered knowledge. Finally, logistic regression analysis was applied to explore risk factors for fatal GA aircraft takeoff accidents. Lists of key causal and contributing factors were revealed and discussed from the analytical results. The identification of causal factors, contributing factors and risk factors for GA aircraft takeoff accidents are expected to be a valuable supplement to existing knowledge for aircraft accident prevention.

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Flight safety improvement has been one of the fundamental objectives for all aviation stakeholders for decades. A variety of flight safety enhancement measures have been undertaken globally to mitigate aviation risks. With continuous effort and collaboration among aviation stakeholders, the total number of aviation fatalities and the accident rate have decreased over the last decades. However, according to the General Aviation Manufacturers Association (GAMA), in the year of 2017 alone, the general aviation (GA) community operated more than 446,000 aircraft flying worldwide with 1,233 accidents in the U.S., which was around 5.67 accident per million flight hours (General Aviation Manufacturers Association [GAMA], 2018). National Transportation Safety Board's (NTSB) statistics show GA was accountable for around 76 percent of total air transport related accidents and incidents in the U.S. between 2014 and 2019 (National Transportation Safety Board [NTSB], 2019). Aircraft accident investigation is "a process conducted for the purpose of accident prevention which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and, when appropriate, making of safety recommendations" (International Civil Aviation Organization [ICAO], 2016, p.13). With the purpose of preventing future accidents, aircraft accident investigation seeks to answer how and why accidents take place. Accurately identifying and understanding of the causes of aircraft accidents are critical for the development of practical safety recommendations for future accident prevention. Approximately 80 percent of aircraft accidents are due to human errors and the other 20 percent are caused by machine failures (Rankin, 2007). Reviewing aircraft accident statistics, investigation reports, and published aviation safety studies, a number of causal factors and occurrence categories were revealed in various accident scenarios for different types of operations. Loss of Control In-Flight (LOC-I), runway excursion, and Controlled Flight into Terrain (CFIT) are the three most common fatal accident categories in scheduled commercial jet airplanes, with primary contributing factors of safety management failure, adverse weather conditions, and flight crew errors of standard operating procedure (SOP) adherence during the years of 2014-2018 (Boeing, 2018; International Air Transport Association [IATA], 2019). For the GA operations – in addition to the CFIT and the LOC-I, system component failure – powerplant and unintended flight in Instrument Meteorological Conditions (IMC) are among top ten leading causes of fatal GA accidents during 2001 - 2016 identified by the Federal Aviation Administration (FAA) (2018).

Given the high accident rate and the diversity of the GA fleet and pilots, the FAA made the goal of reducing the general aviation accident rate one of its top priorities; and, set a goal of "no more than 1 fatal accident per 100,000 hours of flight by 2018" (FAA, n.d., p. 4). A number of studies on GA aircraft accident analysis and prevention have been published from a variety of important perspectives. The primary causal factors for GA aircraft accidents vary depending on the perspectives of the studies. Based on the GA accident and incident data between 1984 and 2004, the FAA (2005) published a high-level analysis of the major causal factors of GA accidents for various categories of aircraft. The study presented causal factors based on aircraft categories, which could be valuable for aircraft manufacturers for aircraft safety design improvement. However, the growing age of the GA fleet and slow replacement of aging GA aircraft make this study subject to validation using more recent data. Specifically considering the different flight profiles and performance characteristics, Boyd (2015) studied accidents of non-commercial twin piston engine GA aircraft. Results of Boyd's (2015) study revealed that most fatal accidents under visual weather conditions were attributed to: malfunction with a failure to follow single engine procedures, poor instrument approach procedures, and failure to maintain obstacle clearance with low visibility (or night). From the perspective of operational environment of mountainous and high elevation terrain (MEHET) for GA aircraft, Aguiar, Stolzer, and Boyd (2017) revealed that CFIT and wind gusts/shear were the most frequent accident causal factors. Taking pilot certification into account, the causes of fatal accidents were studied for instrument-certified and non-certified private pilots (Shao, Guindani, & Boyd, 2014).

Based on the findings of relevant aircraft accident studies, safety recommendations were proposed by researchers from different perspectives. For example, turbo-charged-powered airplanes and flying under IFR were encouraged for operations with MEHET, additional training of twin-engine IFR night operations was recommended for twin-engine GA pilots, and regulatory oversight, safety management system, and SOP-checking were suggested to be reinforced for commercial air transportation (Aguiar, et al., 2017; Boyd, 2015; IATA, 2019). However, existing research publications on aviation accidents typically consider the factors of operational environment, types of operations, and types of aircraft. Moreover, the research results usually tend to cite generic causes such as: pilot errors, aircraft issues, and weather-related conditions. Unfortunately, the analyses of specific causal factors often fail to distinguish between phases of flight.

Purpose

Aircraft and flight crew perform differently during each phase of flight given the changes of aircraft configuration, operational environment, and flight crew workload. As a result, aircraft accidents distribute differently by phase of flight. According to NTSB (2019), the distribution of GA aircraft accidents by phase of flight is shown as Figure 1. Around 40 percent of GA aircraft accidents from January 2013 to January 2018 occurred during the landing phase, followed by the takeoff phase with nearly 24 percent of total accidents. Similar to GA, Boeing (2018) indicates that commercial jet aircraft fatal accidents and onboard fatalities are distributed with a similar pattern. Nearly half of worldwide commercial jet airplane fatal accidents from 2008 to 2017 occurred during the final approach or landing phase of flight. These accidents accounted for 1,003 on-board fatalities, or around 44 percent of total on-board fatalities, followed by the takeoff phase and initial climb with 14 percent of fatal accidents (Boeing, 2018).

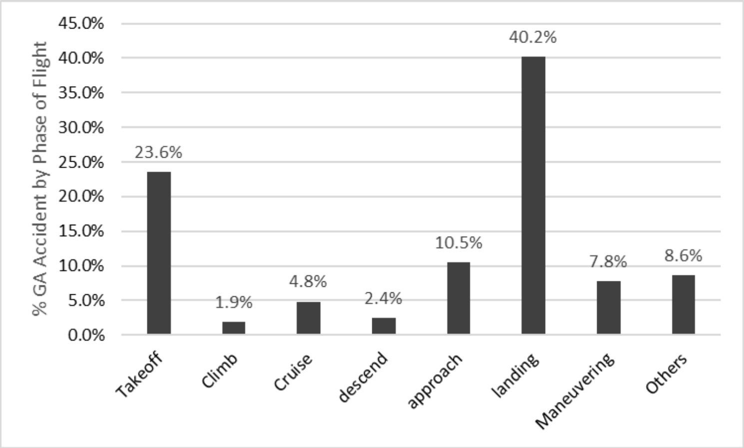


Figure 1. Distribution of GA aircraft accidents by phase of flight through January 2013 to January 2018 (NTSB, 2019).

Global aviation accident statistics show that final approach, landing, takeoff and initial climb are critical phases of flight for safety. During the phases of final approach and landing, aircraft are close to the ground with a more vulnerable configuration in preparation for landing. The crew operates with a high workload and decreased maneuver margins. Similarly, fatal accidents are also likely to occur during the takeoff and initial climb stage, given low flight altitude and limited aerodynamic capabilities. Because of the high accident rate, the final approach and landing phases have drawn more attention in aircraft accident studies in comparison to the takeoff and initial climb phases. Numerous studies have been published on GA aircraft accident prevention at final approach and landing phases of flight by analyzing and modeling operational flight data. For example, one of the early studies on the risk factors for pilot fatalities in GA aircraft crash landings suggested that the use of lap and shoulder restraints could reduce risk of death in GA crash landings (Rostykus, Cummings, & Mueller, 1998). Pilot performance, workload, and aircraft factors affecting pilot performance while executing final approach and landing were explored in different studies from the human factors standpoint (Boehm-Davis el al., 2007; Lee, 2010).

However, a review of the literature shows that few studies have been done to explore the causal factors of GA aircraft accidents during takeoff. Given the second highest GA accident rate occur during takeoff, it is critical to understand the primary causes for GA accidents occurring during this phase. With a better understanding, more effective and comprehensive aircraft accident prevention strategies could be developed and applied by pilots across different types of operations, aircraft, and operational environments. This paper presents research on the analyses of GA aircraft accidents during the takeoff phase of flight using historical aircraft accident information released by the NTSB.

In this research, the following research questions were studied:

1. Does the phase of takeoff pose a high risk for GA aircraft accidents?
2. What are the primary causes for GA aircraft takeoff accidents?
3. What are the contributing factors for GA aircraft takeoff accidents?
4. What are the risk factors for fatal GA aircraft takeoff accidents?

Methods

Data Collection

For this study, GA aircraft accident information was retrieved from the NTSB Aviation Accident Database & Synopses and Summary of U.S. Civil Aviation Accident updated in January 2018 (NTSB, 2019). Aircraft accident records for operations under Title 14 of the Code of Federal Regulation (CFR) Part 91 – General Aviation, occurring between January 2013 and January 2018, were queried. Additional accident data for 14 CFR Part 121 – Air Carrier and worldwide non-U.S. commercial aircraft and 14 CFR Part 135 – Air Taxi & Commuter during the same time span were also collected for comparative analysis. Because no fatal accidents were recorded from 14 CFR Part 121 operations in the U.S., data on worldwide, non-U.S. commercial operations were collected to reflect the features of Commercial Air Carriers' takeoff accidents. Considering different flight characteristics due to the diverse aircraft categories and purposes of flight, 14 CFR Part 91 aircraft accidents were limited to personal, business/corporate, and instructional flights; and, only non-amateur built airplanes were included in the data query. In addition, available final accident investigation reports were retrieved to supplement causal and contributing factor information. Fatal outcome, causes, and contributing factors were determined per the NTSB reports (NTSB, 2019). The total annual flight hours for the 14 CFR Part 91 operations for the selected flight purposes were obtained from the FAA survey to determine accident rate (FAA, 2019). Given above criteria, 3,939 14 CFR Part 91 aircraft accidents comprised of 826 takeoff accidents and 3,113 non-takeoff accidents were collected in this analysis. Given the NTSB preliminary accident reports do not present causal factors, 721 final reports for GA takeoff accidents were retrieved from the NTSB database for causal factor analysis. Each phase of flight was defined by ICAO Common Taxonomy (ICAO, 2013). The phase of flight for each accident was determined by the NTSB. Accident causes and causal factor categories used in analysis were identical to the NTSB final reports.

Analytical Procedure

Focusing on analyzing the causes, contributing factors, and risk factors of GA aircraft takeoff accidents, the following analytical work was conducted:

1. A comparative study of aircraft takeoff accidents in 14 CFR Part 91, 14 CFR Part 135, and 14 CFR Part 121 operations was presented employing descriptive statistics and Chi-square tests.
2. Focusing on Part 91 operation, the Chi-square linear-by-linear association output was used for trend assessment of GA aircraft takeoff accidents.
3. A list of primary causes for fatal GA accidents during takeoff was developed from the NTSB final accident investigation reports.
4. Based on the identified primary causes, the associated contributing factors were explored employing text mining techniques.
5. Logistic regression analysis was employed to identify risk factors for fatal GA takeoff accident based on 95% confidence intervals.

The data collected from the NTSB database consists of two categories: *structured data* from the Summary of U.S. Civil Aviation Accident and NTSB Aviation Accident Database & Synopses; and, *unstructured text information* from the NTSB aircraft accident investigation reports. The structured data were used for the first and second analytical tasks described above. The unstructured data were transformed into structured data for the third and fourth analytical tasks. The fifth analytical task was conducted by analyzing the fused structured and unstructured data.

Results and Discussion

Comparative Study of Aircraft Takeoff Accidents

The distribution of GA aircraft accidents by phase of flight (Figure 1) shows the takeoff phase of flight accounts for around 23.6 percent of total GA aircraft accidents. However, the fatal accident rate would more effectively reflect the significance of GA aircraft takeoff accidents by eliminating the portion of non-fatal accidents. The number of aircraft departures and passenger departures are two effective denominators for aircraft fatal accident and fatality rates, respectively. However, no statistics of the number of aircraft and passenger departures are available for GA operations. In addition, the number of *fatal accidents per hours flown* is not expected to be an appropriate measurement for aircraft takeoff accidents given the duration of takeoff only counts for a small portion of entire flight duration. In this study, the percentages of fatal takeoff accidents in the total number of takeoff accidents, and the takeoff fatalities in the total fatalities were employed to reflect the fatal accident rate and fatality rate of aircraft takeoff accidents. Figure 2 shows these two percentages for 14 CFR Part 91, Part 135, Part 121 and Non-U.S. commercial operations, respectively, according to the retrieved data from January 2013 to January 2018. Approximately 32 percent of GA aircraft takeoff accidents were fatal accidents comprising 22 percent of fatalities of all GA aircraft accidents during the studied timespan.

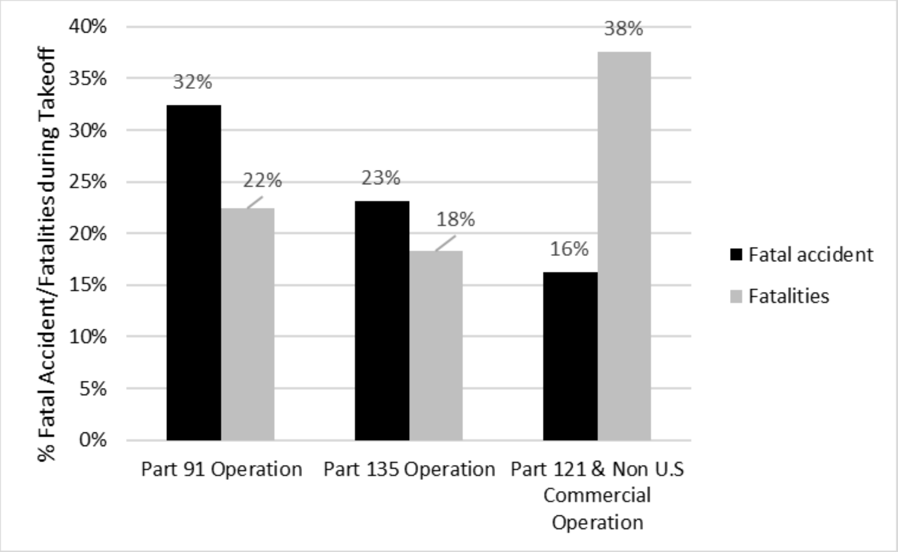


Figure 2. Percentages of fatal takeoff accidents and takeoff fatalities of GA aircraft accidents through January 2013 to January 2018.

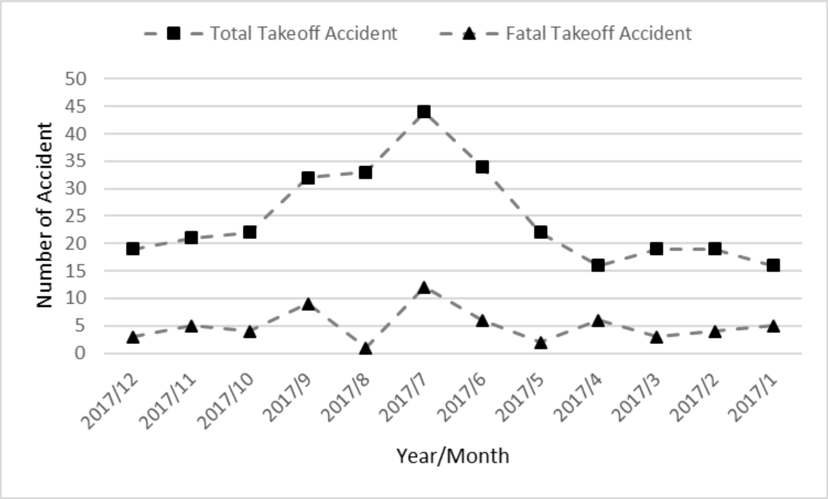
To examine whether different types of operations have similar takeoff accident patterns, a Chi-square test was applied to compare the ratios of takeoff accidents versus non-takeoff accidents across Part 91, Part 135, and Part 121 & worldwide non-U.S. commercial operations. The *p*-value ($p = .004$, $\alpha < .05$) of the test indicates a rejection of null hypothesis, therefore the tested ratios of the three types of operations were statistically different from each other, as shown in Figure 3.

	Part 121 & Non-U.S. Commercial	Part 135	Part 91
■ Takeoff accident	9	36	826
□ Non-takeoff accident	111	123	3113

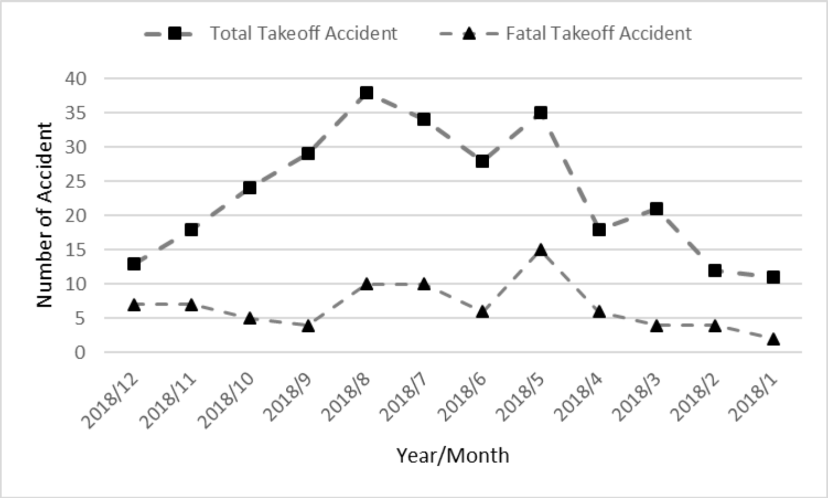
Figure 3. Ratio of takeoff accident versus non-takeoff accident, $p = .004$, $\alpha < .05$.

Temporal Trend of GA Aircraft Takeoff Accidents

Further exploration of the NTSB aviation accident statistics show that GA aircraft takeoff accidents occurred frequently in recent years. As shown in Figure 4, in 2017 and 2018, at least 10 GA aircraft takeoff accidents occurred every month in the U.S., and this number increased dramatically in the summer. The number of fatal takeoff accidents involving GA aircraft fluctuated accordingly. Analysis of the temporal trend of takeoff accidents provides better understanding of this particular type of aircraft accidents (Boyd, 2015). For a test of temporal trends of GA aircraft takeoff accident proportions across the studied timespan, a Chi-square linear-by-linear association value was used to determine the trend (Agresti, 2012; Boyd, 2015). In addition, Chi-square test was also used to determine if a difference in takeoff accidents comparing the initial time of 2013 and a subsequent period was statistically significant. The percentages of GA aircraft takeoff accidents in the total number of accidents for the corresponding time period are shown in Figure 5. The *p*-values indicate the statistical level relative to the takeoff accident percentage in 2013. The Chi-square linear-by-linear association is yielded $p = .285$, $\alpha < .05$, therefore, there was no statistically significant linear trend across all studied years. However, the *p*-value of Chi-square test comparing 2015 to 2013 ($p = .021$, $\alpha < .05$) shows a statistically significant increase of takeoff accidents in 2015.



(a)



(b)

Figure 4. Total takeoff accident and fatal takeoff accident through (a) 2017 to (b) 2018.

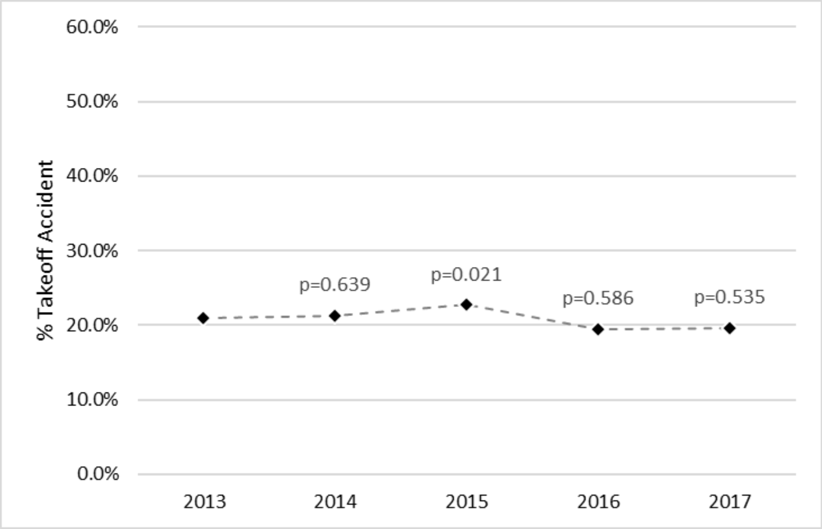


Figure 5. Temporal trend of GA aircraft takeoff accident percentage; *p*-values indicate the statistical level relative to the takeoff accident percentage in 2013.

Causes and Contributing Factors for GA Aircraft Takeoff Accidents

Each NTSB aircraft accident investigation report contains basic accident information (index), an analysis narrative, flight events, probable cause, findings, information about involved pilot(s), aircraft, meteorology, airport, wreckage and impact, and investigation administrative information. In the NTSB reports, accident causes and contributing factors were identified and categorized by aircraft issues, personnel issues, environmental issues, and organizational issues. Aircraft issues include aircraft mechanical problems or aircraft system related failures, personnel issues refer to related human errors, environmental issues include weather and all other flight operational environmental related factors, and organizational issues include all casual or contributing factors from organizational level.

Since the causes and contributing factors were presented in the form of unstructured data, text mining techniques were employed in this study to explore the patterns of text information to identify variables of primary causes of GA takeoff accidents. By analyzing the text file of aggregated NTSB reports in chronological order, four categories of causes were distributed (as shown in Figure 6). The horizontal axis divides the aggregated file into ten segments from 1 to 10, the tenth segment contains the most recent GA takeoff accidents. The vertical axis shows the relative frequencies for four categories of causes cited in the file with the total number of words as the denominator. According to this graph, aircraft issues are the most frequently cited causes during the studied time period, but there is evidence of a decreasing trend in recent years. Both personnel issues and environmental issues follow similar trends across the timespan. Organizational issues are the least frequently cited as GA takeoff accident causes, but more instances have been observed in recent years.

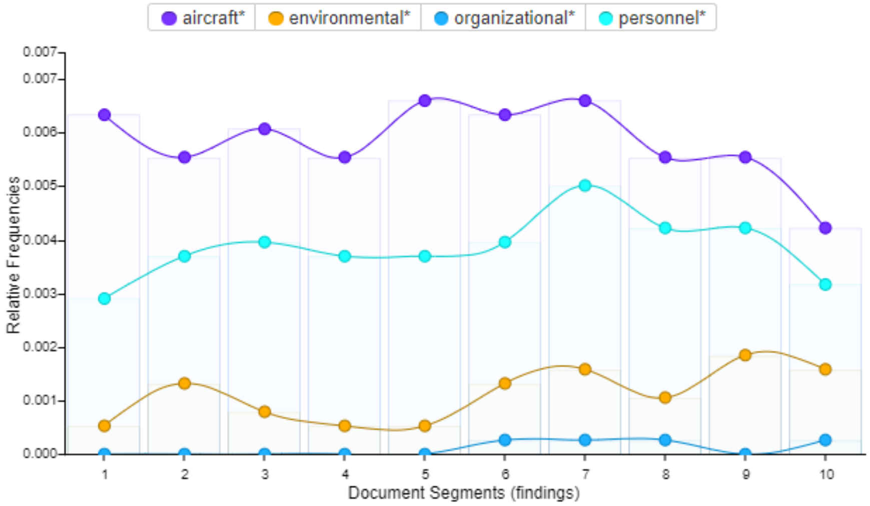
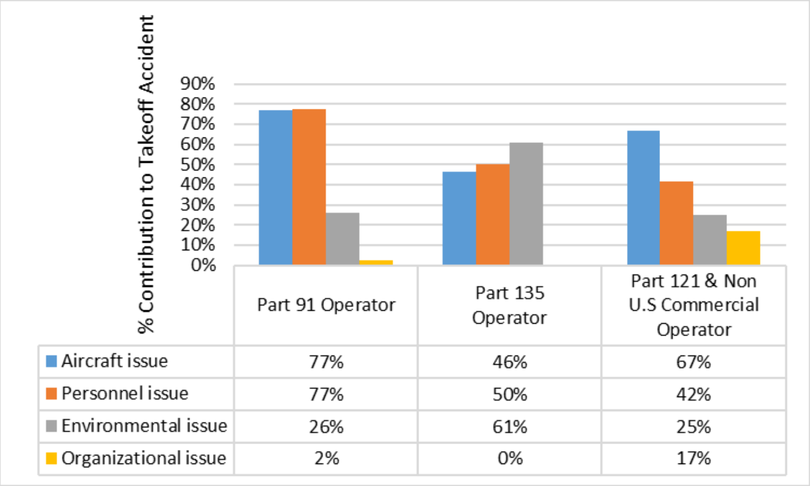


Figure 6. Distribution of four categories of causes in fatal GA takeoff accident reports

An aircraft accident is usually a consequence of multiple contributing factors (Reason, 1990; Hawkins & Orlady, 1993; ICAO, 2018). Most NTSB reports cite more than one accident cause or contributing factor from four categories discussed above. It is impractical to claim a single issue as the cause for an individual accident. Therefore, the percentage of each category being cited by accident reports was used to measure the significance of that category of causes. For instance, 77% of retrieved Part 91 aircraft takeoff accident reports cited aircraft issues as accident causal factors (see Figure 7). Figure 7 presents a latitudinal view of categorical causes for GA aircraft takeoff accidents in comparison with Part 135 and Part 121 & Non-U.S. commercial operations. It is noticeable that Part 91 aircraft takeoff accidents are more likely attributed to personnel issues and aircraft issues while Part 135 aircraft takeoff accidents cited more environmental issues and Part 121 & Non U.S. commercial aircraft takeoff accidents cited more organizational issues.



	Part 91 Operator	Part 135 Operator	Part 121 & Non U.S Commercial Operator
🟦 Aircraft issue	77%	46%	67%
🟧 Personnel issue	77%	50%	42%
▨ Environmental issue	26%	61%	25%
🟨 Organizational issue	2%	0%	17%

Figure 7. Contribution of categorical causes to fatal takeoff accident.

By parsing the aggregated text reports, the most commonly used phrases and causes identified by the NTSB reports are shown in Figure 8 and Figure 9. Most common phrases related to accident causes are shown in Figure 8. The five most common causes for GA aircraft takeoff accidents are listed in Figure 9: Aircraft Control Deficiency, Angle of Attack Exceeded, Airspeed not Attained/Maintained, Decision Making Mistake, and Fuel System Failure. The bar graph describes the number of accident reports by the type of cited cause. The line graph represents the cumulative percentage of reports by the type of cited cause. For example, Aircraft Control Deficiency was the most cited cause in 88 accident reports, which accounts for 38% of the GA aircraft accident final reports analyzed in this study.

Figure 8. Key phrases related to accident causes.

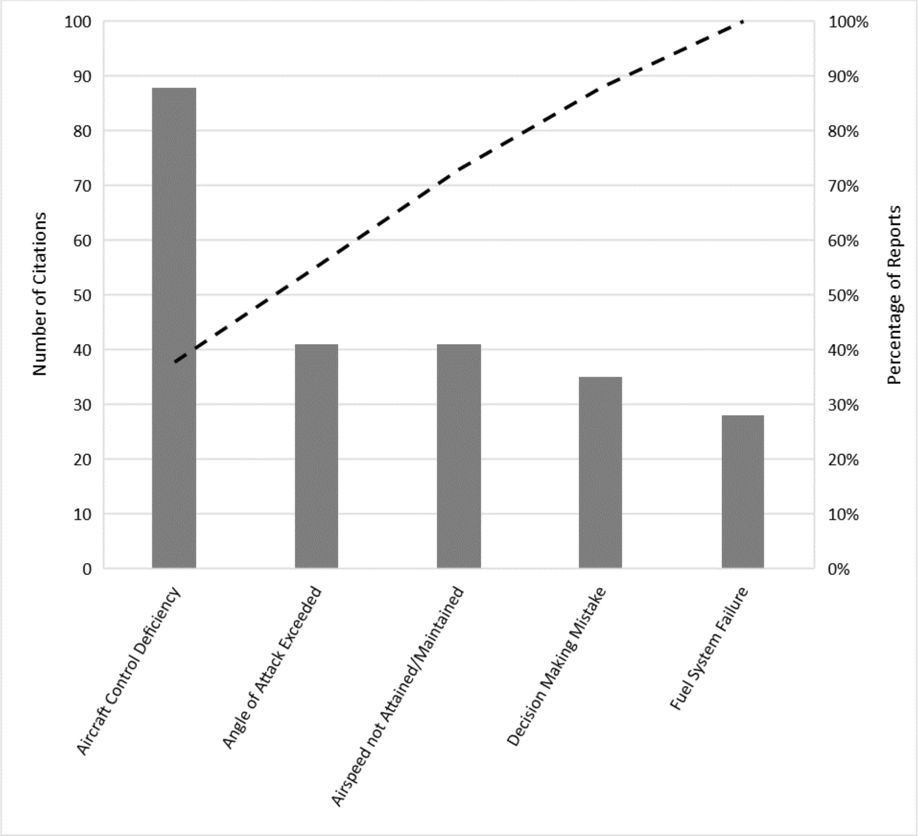


Figure 9. Primary causes cited by GA aircraft takeoff accident final reports.

The primary causes identified by the NTSB could guide aviation stakeholders to a consensus about where GA aircraft takeoff risk mitigation work should concentrate. However, classic aviation accident analysis models and strategies, such as the "Swiss Cheese" model and accident causal chain, the SHELL model, and the Human Factor Analysis and Classification

System (HFACS), have recognized that aircraft accidents result from a series of unsafe events consisting of leading causes and contributing factors. A good understanding of associated contributing factors and the relationship between cause and contributing factor are expected to be important to discover effective means for aircraft accident prevention. Iterative text analysis was conducted for the identified five primary causes for the purpose of finding the most related contributing factors. Voyant Tools, an open-source text analysis software, was used for text mining (Sinclair, Rockwell, & Voyant Tools Team, 2012). The Pearson's correlation coefficient was used to explore the associated factors (Sinclair et al., 2012). The correlation coefficients were calculated by comparing the relative frequencies of identified causes and contributing factors. However, the use of Pearson's correlation coefficient was based on the assumption of normally distributed data. In addition, the relative frequencies of causal and contributing factors are relatively small given the same contributing factor could be expressed in different phrases of natural language. A relatively big confidence level of 80% was used as the cut-off value to select contributing factors. The results are shown in Table 1. The correlation analysis of text information was primarily used to explore associated contributing factors; further validation with a larger dataset might be necessary.

Table 1.
Associated contributing factors

Cause	Associated Contributing Factor	Correlation Coefficient	Significance (*p*)
Aircraft control deficiency	Directional control not attained/maintained	0.656	0.039**
	Recent experience	0.601	0.066*
	High density altitude takeoff	0.498	0.143
	Instructor/check pilot incorrect actions	0.492	0.148
Critical angle of attack exceeded	Elevator control failure	0.681	0.03**
	Lateral control failure	0.627	0.052*
Airspeed not attained/maintained	Flight control system malfunction	0.475	0.165
	Center of gravity exceeded capability	0.403	0.196
Decision making	Spatial disorientation	0.615	0.058*
	Drug effect	0.545	0.103
	Monitoring communications	0.483	0.158
	Instructor/check pilot incorrect actions	0.459	0.183
Fuel	Fuel distribution failure	0.908	0.001**
	Fuel selector valve damage	0.847	0.002**
	Fluid level incorrect	0.597	0.068*

Note. Associated contributing factors were selected with cut-off significance level of 20% (*p-value* < 0.2), ** indicates the coefficient is significant at 5% level, *indicates the coefficient is significant at 10% level.

For the five primary causes, *directional control not attained or maintained* was the contributing factor most highly correlated with aircraft control deficiency; *elevator control failure and lateral control failure* were believed to frequently contribute to the exceedance of critical angle of attack*; spatial disorientation* was a major contributing factor associated with decision making issues; *fuel distribution failure and fuel selector valve damage* were two significant factors resulting in fuel system related accidents. In addition, it is noticeable that some identified contributing factors are identical to other related publications, but some of them are unexpected. One of the unexpected results is that drug effect was recognized as a contributing factor for GA aircraft takeoff accidents, though the Federal Aviation Regulations (FARs) preclude flying while having a condition or taking a medication that might affect flight safety (14 C.F.R. § 91.17, 2006).

Risk Factors for Fatal Takeoff Accidents

Logistic regression analysis using 95% confidence intervals was adopted to identify risk factors for fatal GA aircraft accidents during takeoff, given its advantages over discriminant analysis. For instance, it is robust in the case of a violation of the normality assumption and does not require equal variances within independent variable group (Tabachnick & Fidell, 1996). According to the distribution of categorical causes to fatal takeoff accident (Figure 7) and findings from the literature review, pilot age (Bazargan & Guzhva, 2007), flight experience (Li & Baker, 1999; Bazargan & Guzhva, 2007), pilot certificate (Groff & Price, 2006), instrument rating (Bazargan & Guzhva, 2007; Boyd, 2015), weather condition (Li & Baker, 1999; Groff & Price, 2006; Bazargan & Guzhva, 2007; Boyd, 2015), number of engine (Bazargan & Guzhva, 2007), type of engine, and season of the year were selected as independent variables for logistic regression analysis. Table 2 presents selected variables with corresponding coding descriptions.

Table 2.
Variables for logistic regression analysis

Variable	***Coding***	***Description***
Type of Accident	0	Non-fatal takeoff accident
	1	Fatal takeoff accident
Pilot Age	Log(age)	Log transformation
Flight Experience by Hours Flown	Log(hours)	Log transformation
Pilot Certificate	0	Student pilot certificate
	1	Private pilot certificate
	2	Commercial pilot certificate
	3	Airline Transport Pilot certificate
Instrument Rating	0	No
	1	Yes
Weather Condition	0	Visual Meteorological Conditions (VMC)
	1	Instrumental Meteorological Conditions (IMC)
Number of Engine	0	Single engine
	1	Twin engine
Type of Engine	0	Reciprocating
	1	Turbo Prop
	2	Turbo Fan
Season of the Year	0	Spring (March to May)
	1	Summer (June to August)
	2	Fall (September to November)
	3	Winter (December to February)

The model is expressed as Equation (1).

$$Fatal_i = a_1 log(age) + a_2 \log(experience) + a_3 Certificate_i + a_4 Rating_i + a_5 Weather_i + a_6 EngineNum_i + a_7 EngineType_i + a_8 Season_i + b + e_i$$

Table 3 presents the parameter estimates from the logistic regression model. Wald Statistics is used to test the statistical significance of each coefficient in the model. Odds ratios are the probability of occurring over the probability of not occurring for an event. The regression results indicate that the model is able to correctly classify 80.1% of the cases into fatal or non-fatal takeoff accident with statistical reliability at 10% significance level (Chi Square $p = 0.098$). In addition, three coefficients are statistically significant at the 5% level: weather condition (IMC vs. VMC), number of engines (single engine vs. twin engine), and season of the year (spring, summer, fall, vs. winter). More specifically, IMC, twin engine, and season of the year were identified as risk factors for fatal GA aircraft takeoff accidents.

Table 3.
Logistic regression parameter estimates and odd ratios

Variable	***Coefficient***	***Wald Sig.***	***Odds ratio***	***95% CI in odds***	
				Lower	***Upper***
Pilot Age	0.003	0.715	1.003	0.989	1.017
Flight Experience	0.000	0.272	1.000	1.000	1.000
Pilot Certificate	0.291	0.144	1.338	0.905	1.977
Instrument Rating	-0.122	0.666	0.885	0.509	1.539
Weather Condition	2.344	0.000*	0.096	0.034	0.269
Number of Engines	1.053	0.004*	2.969	1.417	6.219
Type of Engine	0.585	0.153	1.795	0.804	4.008
Season of the Year	-0.258	0.019*	0.772	0.622	0.959
Constant	0.717	0.309	2.047		

Note, * indicates statistical significance at the level of 5%; *CI* – Confidence Intervals.

Conclusion

Despite accounting for the second most number of fatal GA accidents, the literature largely ignores accidents occurring during the takeoff phase of flight. In response, this study verified the assumption of high risk of GA flight operations during the phase of takeoff, analyzed the causes and contributing factors for GA aircraft takeoff accidents, and explored risk factors for fatal GA takeoff accidents using available aircraft accident information from the NTSB database from January 2013 to January 2018.

In comparison with aircraft accident in Part 121 and Part 135 operations, GA operations show higher ratios of takeoff accidents vs. non-takeoff accidents and fatal takeoff accidents vs. non-fatal takeoff accidents. The results indicate that takeoff accidents are statistically more frequent and risky for GA compared to Part 135 and Part 121 operations, and no temporal change of GA takeoff accidents was observed statistically across the studied years. The findings of descriptive analyses of aircraft accident data support the author’s assumption and motivation on this study topic: GA operations face significant risk during the takeoff phase of flight which may result in fatal accidents.

Unlike Part 135 and Part 121 operations, aircraft and personnel related issues were more often cited as causes by accident reports for GA takeoff accidents. The difference might be explained by the limited resources that GA operators allocate to aircraft maintenance, the large number of old GA aircraft, and the diverse background and experience of GA pilots. In general, aircraft control deficiency, angle of attack exceeded, airspeed not attained/maintained, decision making mistake, and fuel system failure were identified as primary leading causes for GA aircraft takeoff accidents.

In addition, a list of 15 contributing factors associated with the primary causes was identified by text mining the final accident investigation reports. Due to the characteristics of natural language used in the NTSB accident reports, a confidence level of 80% was employed as the cut-off value to explore a bigger scope of associated contributing factors for each leading cause. Directional control deficiency, elevator control failure, fuel distribution failure, and fuel selector value damage were identified as contributing factors at 5% significant level; recent experience, lateral control failure, spatial disorientation, and incorrect fluid level were identified at 10% significant level. Surprisingly, drug effect was marginally significant at 10% level though FARs prohibit flying while having a condition or taking a medication that might affect flight safety. However, other identified contributing factors at lower confidence level might also be considered in GA aircraft takeoff accident prevention.

The results of logistic regression analysis present weather conditions, number of engines, and the season of the year as risk factors for fatal GA aircraft takeoff accident. In addition, the analysis results show that IMC and twin engine aircraft increase the likelihood of a GA aircraft takeoff accident to be fatal. GA aircraft takeoff accidents happening in spring and summer are more likely to be fatal than those happening in fall and winter. The weather condition of IMC means that the aircraft was taking off in low visibility or an adverse operational environment, which intuitively explains the high likelihood of fatal takeoff accidents. The finding that twin engine aircraft takeoff accidents are more likely to be fatal stays in line with the narratives in corresponding NTSB accident reports. Pilots encounter serious directional control difficulties while having engine failure of twin engine aircraft during takeoff. There could be many other reasons making the season of year a possible risk factor, but generally, the relatively lower air density and higher air temperature in summer and spring could reduce the aircraft takeoff performance during takeoff.

In conclusion, this study emphasizes the importance and necessity of additional accident prevention strategies for takeoff phase of flight in GA operations. The findings of this study inform GA operators as to the causes of takeoff accidents and where the training should be focused on. For example, improvement of aircraft control proficiency during takeoff in spring and summer, as well as in an adverse weather condition is expected to be beneficial, proficient execution of twin engine aircraft takeoff procedures upon loss of power in one engine should be reinforced in an adverse weather condition. Additionally, findings of this study could be helpful for better identifying possible gaps between current flight training techniques and pilot proficiency standards. In this study, the available aircraft takeoff accident data from the NTSB were categorized by broad phases of flight: Standing, Taxiing, Takeoff, Climb, Cruise, Descend, Approach, Landing, Go-around, Maneuvering, and Others. There was no information explaining whether the aircraft accidents during the phase of climb-out were categorized as part of takeoff accidents or climb accidents. Further research is necessary to verify the accuracy of this study by eliminating data errors because of above reasons.

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Assessing an Aviation Out-of-School Time Program: A Collective Case Study

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Recent hiring trends fueled by a growing shortage of qualified pilots and aircraft mechanics serve to increase the pressure on the aviation community to attract young people to the profession. Given the historical reality that the industry is predominantly white and male, this dynamic supports efforts to increase access to underrepresented populations, including women and people of color. This collective instrumental case study sought to contribute insights and outcomes from providing an aviation module during an Out-of-School Time (OST) program in an underserved, primarily African American neighborhood. Thirty-one youth campers and 12 adult camp counselors participated. Thematic analysis and descriptive statistics were conducted to explore data collected via surveys, worksheets, reflections, and observations. The perspectives and attitudes of the youth and counselors who participated in the program were decidedly positive. The results suggested that the campers were connected, engaged, and motivated, even as they seemed at times to be distracted in the program. Games, worksheets, age-appropriate challenges, and one-on-one supervision were effective in supporting lecture and simulator activities. The outcomes recommend the development of aviation programs with activities closely tailored to age-appropriate academic objectives. Additionally, studies to further understand their value may provide insight into the long-term benefits of youth engaged in such programs.

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Recent hiring trends fueled by a growing shortage of qualified pilots and aircraft mechanics serve to increase the pressure on the aviation community to attract young people to the profession (Boeing, 2019; Brinkmann, 2019). Given the historical reality that the industry is predominantly white and male (Hansen, Oster, & National Research Council, 1997; Ison, Herron, & Weiland, 2016), this dynamic supports efforts to increase access to underrepresented populations, including women and people of color. This paper seeks to contribute insights and outcomes from providing an aviation module during an Out-of-School Time (OST) program in an underserved neighborhood to children of color. Specifically, it seeks to better understand the effects of aviation OST programming from the perspective of the participants.

Background

There are several factors that challenge greater diversity in aviation for African American populations, most notably precedent and access. According to Ison et al. (2016), in 2011, 2.9% of employed professional pilots were African American. Furthermore, between 2004 and 2014, while non-White participation in collegiate aviation programs increased from 17.1% to 22.2%, African American participation increased an insignificant .29% (p. 29). The financial and academic requirements of attaining the requisite qualifications for entry into the aviation workforce likely serve to limit access by such underrepresented groups. As of 2017 (Annie E. Casey Foundation, 2019), African American children made up 33% of children in poverty (highest).

Additionally, 41% of children whose parents lacked secure employment (second highest), and 45% of children living in households with a high housing cost burden (highest) were African American. Regarding academic ability, the data is no less stark. African American youth accounted for 81% of fourth-graders not proficient in reading (highest), 87% of eighth-graders not proficient in math (highest), and 22% of high school students who did not graduate on time (second highest). By comparison, for each of these categories, White children were consistently below the average at the lowest or second-lowest rates. The issue is framed by the sheer lack of a legitimate idea of becoming a pilot or aircraft mechanic (Turner & Lapan, 2003).

In contrast, there is a long-standing tradition to share one’s passion for flight with the younger generations that goes back to the very beginning of the aviation community, and outreach programs remain a popular means for attempting to generate interest (Lutte, 2018). There are a myriad of initiatives designed to introduce young people to the world of aviation and a multitude of lesson plans and programs available for those who wish to provide encounters within the field. Such efforts are supported by research related to OST programs in general and STEM disciplines in particular (Carrick, Miller, Hagedorn, Smith-Konter, & Velasco, 2016; McCombs, Whitaker, & Yoo, 2017; Molina, Borror, & Desir, 2016; National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

OST interventions are shown to address academic performance as well as social behavior (Jenson et al., 2018). For example, Carrick et al. (2016), concluded that a summer high school geoscience program was "a very effective strategy for inspiring interest in and recruitment into the geosciences among Hispanic American high school students" (p. 95). Durlak, Pachan, and Weissberg (2010) explained that in the U.S., the focus on OSTs had increased in recent years and that such interventions were implemented with an expectation of increased personal and social growth.

Methodology

Consistent with the goal of understanding the effects of an aviation OST program from the perspective of underserved African American youth, the researchers adopted a qualitative collective instrumental case study approach (Yin, 2003). An aviation module conducted as part of a month-long summer camp within a neighborhood plagued by low income and high crime was purposefully selected (Creswell & Poth, 2018). Data was collected from two sessions of the camp, offered in July of 2018 and 2019. Six of the initial 11 participants returned for the second year. The age of the campers ranged from 7 to 16 years old, all of whom were African American. The ratio between female and male participants was roughly balanced, with 17 females and 14 males. Twelve camp counselors participated in the camps. The counselors' age ranged from 16 to 23 years old, with seven female counselors and five male counselors. Two counselors were collegiate aviation (flight) students. Participation rates fluctuated weekly for each group as not all campers or counselors were able to participate every week.

The researchers were engaged in the summer camp activities as camp counselors and functioned as participant observers (Ravitch & Carl, 2016). Given their presence as additional counselors, the researchers were able to move from the roles of complete participant, participant as an observer, and nonparticipant observer as needed (Creswell & Poth, 2018). The researchers sought to limit observation bias and disruptions of the activities by collecting observation data by way of hand-written field notes. As circumstances allowed, they would quietly withdraw from activity to make notes. During times when they were in a more active role, they would wait until the end of the activity to collect their observations. Permission to conduct the study was obtained from the Saint Louis University Institutional Review Board (IRB #29032). The applicable consent was obtained from all participants prior to collecting data.

The aviation program occurred twice weekly during each of the four weeks of the camp. Data was collected via surveys, worksheets, reflections, and observations. Weekly satisfaction surveys were conducted at the end of each week for both campers and counselors. Campers also completed an end of the camp survey while the aviation counselors were asked to provide a final reflection. The questions in the surveys were developed based on a number of out of the school time research studies (Harvard Family Research Project, 2004; Kittur, Shaw, & Herrera, 2017; Rudd, Aguilera, Elliott, & Chambers, 2017). Questions for the youth attempted to elicit their attitudes regarding the activities within the aviation module of the camp, while questions for the counselors were developed to understand their perspectives towards youth participation. The surveys included a Likert scale, open-ended, and dichotomous questions. Worksheets included short answer and fill in the blank questions related to the session material. Observations were collected using field notes and included informal assessments and discussions with the campers and counselors.

The following research questions were addressed in the study:

- How did youth participants perceive and assess the aviation portions of the summer camp?
- How did camp counselors perceive youth engagement and participation?
- What were the researcher's observations regarding youth engagement and participation?

Thematic analysis and descriptive statistics were conducted to explore the data. Magnitude, frequency, and in vivo coding were used to develop the themes from the data attained in the open-ended questions and observations (Saldaña, 2009). Frequency distributions were conducted using Microsoft Excel. A data analysis spiral was employed to interpret and refine the findings (Creswell & Poth, 2018).

Results

Camper Perspectives and Attitudes

Eighteen dichotomous questions were developed and randomly distributed during the four weeks of camp. During week 1, there were 26 participants. Of the 26, 24 campers responded that camp counselors helped them when needed and felt comfortable in the program. Twenty-three made new friends (Figure 1).

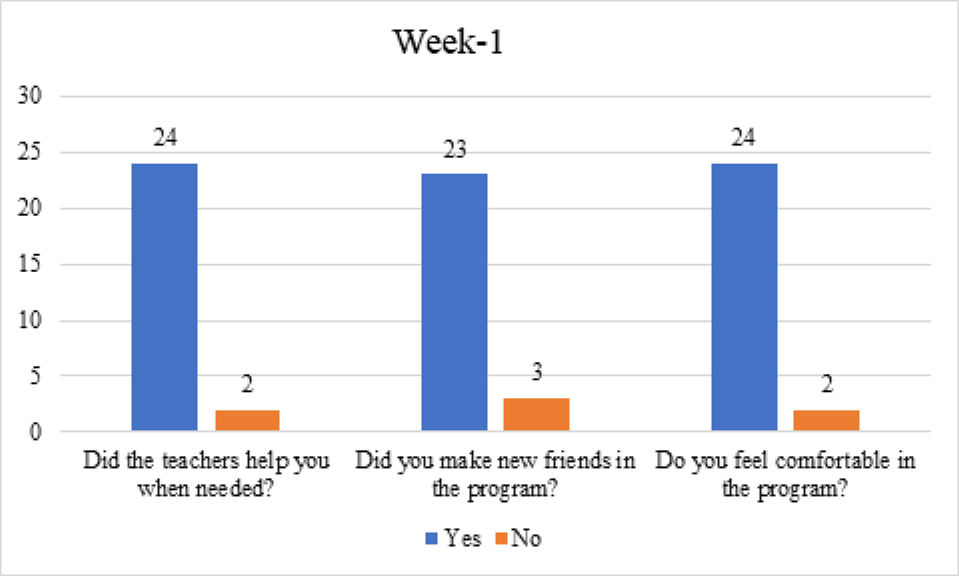

Figure 1. Campers Perspective and Attitudes Data of Week-1.

During the second week, there were 19 participants, of which 16 received answers from camp counselors to their questions, and 17 participants indicated that they trusted the camp counselors. Fourteen responded that they were not bored in the second week. Seventeen believed the program was a great place to be and 13 liked the other kids in the program (Figure 2).

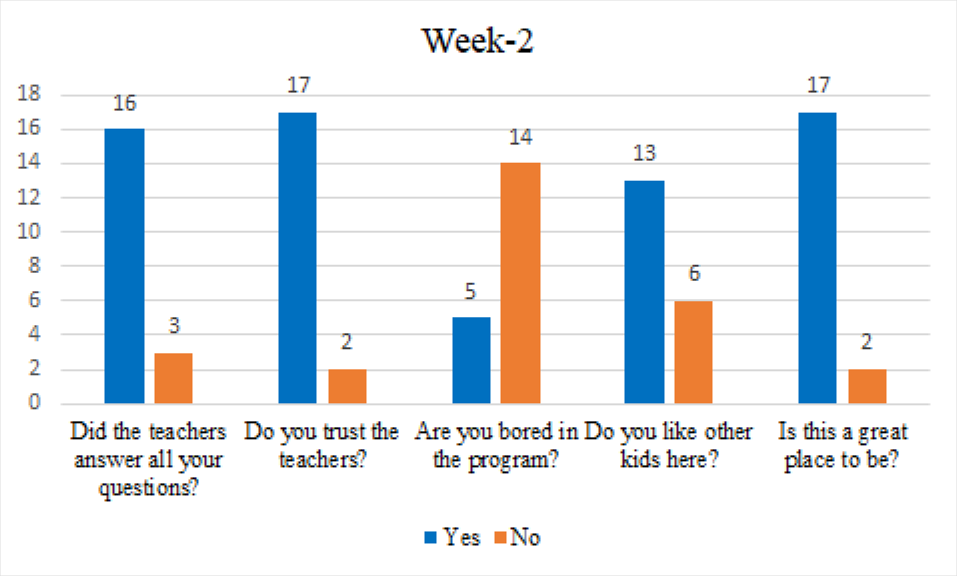

Figure 2. Campers Perspective and Attitudes Data of Week-2.

In the third week, there were a total of 22 campers. All 22 believed that camp counselors cared for them, and 19 talked about the program at home. Sixteen were not bored, and 19 observed that camp counselors understood their feelings. Twenty-one liked coming to the program (Figure 3).

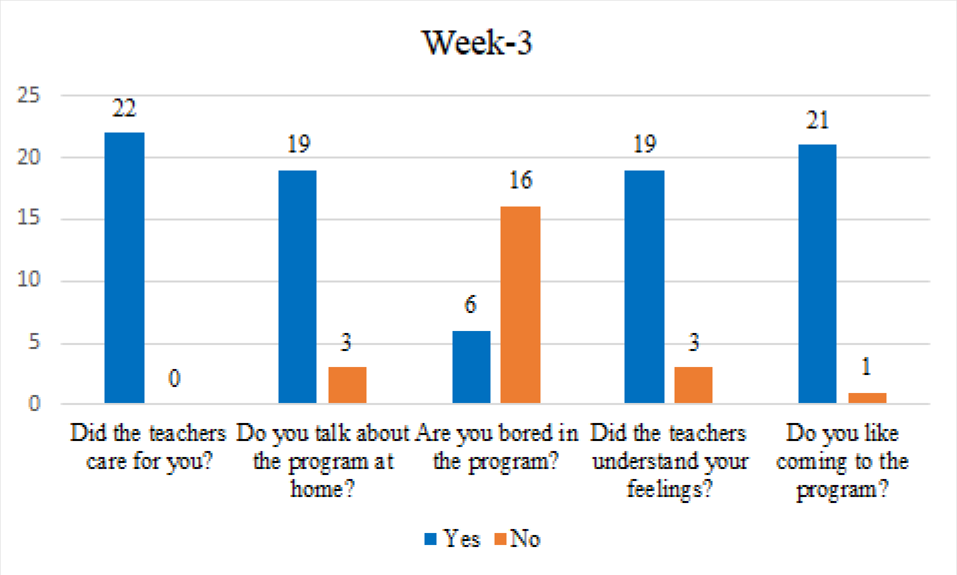

Figure 3. Campers Perspective and Attitudes Data of Week-3.

Out of 25 campers in the fourth week, 21 talked about the program at home, and one participant even mentioned that they discussed the program, “In a good way” at home. Twenty were not bored and liked other kids in the program. Twenty-two developed a good relationship with counselors, remembered the names of the counselors. Twenty-four campers enjoyed the activities (Figure 4).

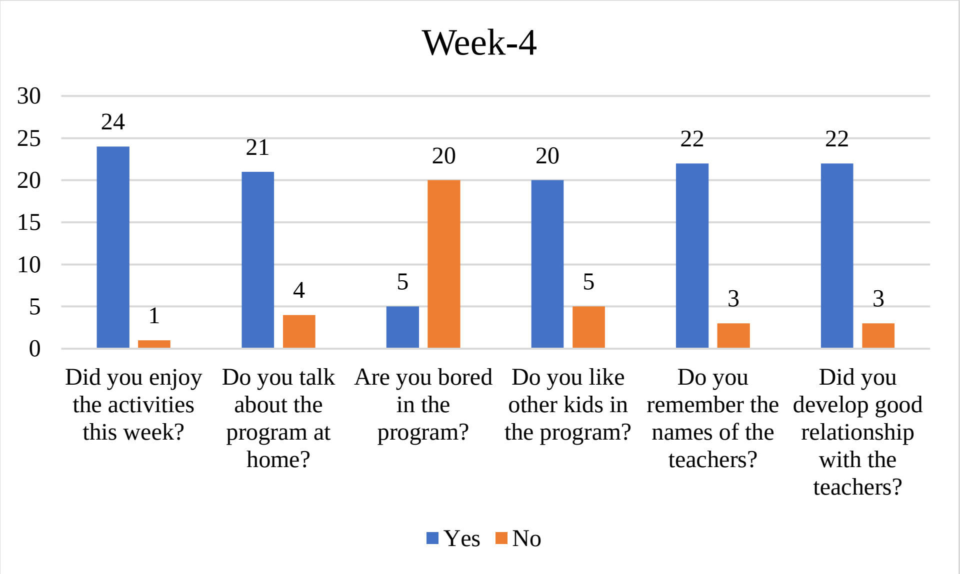

Figure 4. Campers Perspective and Attitudes Data of Week-4.

Camper Weekly Activities Satisfaction

The activity survey questions were Likert scale questions with five options: Loved it, Liked it, Okay, Do not like it, and Hate it (Table 1). Nearly 59% of the responses loved or liked the activities, 11% did not like or hated the activities, and 14% of the responses were neutral (Table 1). Model rocketry was the most popular activity followed closely by flight simulator and water bottle rockets. Interestingly, only 54% of participants (*n* = 6) indicated strongly favorable toward the airplane discovery flight. However, this number is a bit misleading, as the camp was not able to include a flight experience in the second year. Also, of the eleven participants, one chose not to fly, and one was neutral. The remaining three participants did not respond. Thus, it is unclear what to make of the responses. The ATC communications activity received a slightly higher percentage of favorable responses at 57%. Presentations and lectures were the least popular with 40% favorable, 22% neutral, and 22% negative responses.

Each week the campers were asked four open-ended questions to elicit what they liked, disliked and learned that week, and if they had any suggestions for the program. Responses regarding the various activities were generally consistent with the data noted above. Participants stated they liked activities like model rockets, launching the rockets flight simulator, water bottle rockets, and taxiing. Out of 92 responses for what they liked, 46 included aviation aspects, 22 of which specifically noted flight simulators. Regarding what campers disliked in the program, 46 offered no response. Fourteen responses were about aviation, most of which were about flight simulator. Fourty-six respondents stated they learned something about aviation each week, for example: “Do not pull up the yoke too much;” “I learned how to do bottle rockets;” and, “Thrust weight lift yaw.”

None of the campers provided any suggestions for the camp. Instead, most of them expressed appreciation for the camp counselors and the program with comments like: “Thank you;” “Keep it up;” “It was cool;” and, “It is Amazing.”

Table 1
Weekly Activities Satisfaction Data

Activity	Year	Love it (%)	Like it (%)	Okay (%)	Do Not Like it (%)	Hate it (%)	N/A (%)	*n*
Model Rockets	2018	66.67	20.00	13.33	0.00	0.00	0.00	15
Flight Simulator	Both	60.44	12.09	6.59	1.10	4.40	15.38	91
Water Bottle Rocket	Both	65.00	5.00	15.00	0.00	0.00	15.00	20
ATC Comms.	2019	42.86	14.29	17.86	3.57	7.14	14.29	28
Discovery Flight	2018	54.55	0.00	9.09	0.00	0.00	36.36	11
Four Forces	Both	33.33	22.22	11.11	5.56	11.11	16.67	18
Phonetic Alphabet	2019	30.00	25.00	20.00	0.00	5.00	20.00	20
Presentations & Lecture	Both	29.07	10.47	22.09	6.98	15.12	16.28	86
Total		46.02	12.80	14.53	3.11	7.96	15.92	289

Camper End of Camp Survey

Twenty-five campers completed the end of the camp survey (Table 2). A 10-point scale was used to evaluate the overall aspects of the program. The responses were mostly positive. Of 25 responses, 20 strongly agreed/agreed that they liked the program overall. Specific to the aviation program, 24 indicated they strongly agreed/agreed they liked aviation. Twenty-two of the respondents indicated they strongly agreed that they would recommend the program to other children. Twenty-two respondents also strongly agreed they liked flying the simulators. Twenty-three strongly agreed/agreed that the camp counselors were friendly and helpful, and 19 indicated they would attend the camp again. Most campers felt they understood the four forces with 16 strongly agree and five agree responses. Quizzes were less favorably rated with 14 strongly agree, four agree, three neutral, two disagree, and two strongly disagree. Finally, the question with the greatest number of negative responses was, “will you become a pilot in the future.” Nine respondents indicated strongly agree, with three selecting agree, and five neutral. The remaining eight responses were strongly disagreed.

The campers were asked three open-ended questions about what they liked, disliked, and if they had any suggestions about the program. Thirteen participants wrote that they liked the program. Specifically, seven participants mentioned either “Aviation” or “Flight Simulator,” while the remaining six wrote “Everything.” One participant added that they liked doing, “Different things each year.” Most of the participants did not have any dislikes in the program. Out of 24 responses, 15 mentioned “Nothing” when asked what they disliked. One participant stated that they did not like the flight simulator.

Table 2
Child End of Camp Survey Data

Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	*n*
How much do you like the program overall?	18	2	4	0	1		25
Do you like aviation?	23	1	1	0	0		25
Do you recommend this program to other children?	22	0	1	1	1		25
Do you like flying aircraft simulator?	22	0	1	1	1		25
Are the teachers friendly and helpful in the program?	20	3	1	0	1		25
Will you attend the program again?	18	1	3	1	1	1	25
How much did you understand the forces of the airplane?	16	5	3	0	1		25
The questions in the quizzes are easy to answer. Rate it.	14	4	3	2	2		25
Will you become a pilot in the future?	9	3	5	0	8		25

Responses obtained from weekly satisfaction surveys were consistently constructive and optimistic. Campers responded positively to attributes like comfortability in the program, making new friends, trusting teachers, liking other kids, coming to the program, and talking about the program at home. Flight simulators and model rockets were the most popular activities of the program, while presentations and lectures were least favored. Most of the campers strongly agreed that they liked aviation, liked flying the simulator, and would recommend the program to others.

Counselor Satisfaction Data

Camp counselor satisfaction data were collected each week and included ten survey questions and three open-ended questions. There were a total of 45 satisfaction surveys from the 12 camp counselors. The results indicated strong support for the weekly activities. Counselors agreed or strongly agreed that the campers were friendly and relaxed, listened, and responded, enjoyed, contributed, and engaged in the activities, and developed peer relationships. The strongest positive response indicated that the counselors believed the activities were helping to develop campers' critical thinking skills. Twenty-four responses indicated that the counselors thought the campers were easily distracted. However, counselors were generally positive regarding knowledge carryover from previous weeks, with 29 responses of strongly agree or agree and 7 disagree/strongly disagreed when asked if the children showed knowledge from the previous week's activities. The most varied responses were to the question of campers discussing their problems with the counselors (Table 3).

Table 3
Camp Counselor Weekly Satisfaction Survey

Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Are the children friendly and relaxed in the program?	19	17	7	1	1
Did the children listen to you actively and respond accordingly?	17	18	9	1	0
Did the children contribute ideas and opinions about the activities this week?	18	18	9	0	0
Did the children enjoy the activities?	17	22	6	0	0
Did the children engage in the activities?	18	20	7	0	0
This week do the children show knowledge from previous week activities?	17	12	9	1	6
Are children developing peer relationships?	27	11	7	0	0
Did the children distract easily?	10	14	11	7	3
Did the children discuss their problems with you?	7	16	12	4	6
Do the activities develop critical thinking skills in children?	23	17	4	0	1

Counselor Open-Ended and Reflection Data

Open-ended feedback from the counselors pointed to a number of strengths and weaknesses of the camp structure and delivery. Of 45 responses, 20 responses indicated “Nothing” or “N/A” regarding things they disliked about the camp. Negative comments tended to focus on frustration with a lack of attention or engagement in an activity. Several responses focused on the age or experience level of the campers and the level of difficulty or repetition of the activity. For example, one counselor commented, “we spent too much time reviewing, which prevented the kids from really exploring the new simulator set up/directions.” Another echoed this perspective, “this activity was a little bit too simple for the students who have retained knowledge from before.” On the other hand, several responses supported repetition. Likewise, there was support for the development throughout the aviation modules. One counselor observed, “kids made connections between discussion & previous experience.”

Counselors also pointed to activities that they liked. The use of computer-based flight simulation was consistently listed as a positive. The incorporation of worksheets and lectures were mentioned as well. One response commented on the combination of the worksheet and simulation sessions, “worksheets with sim lessons were effective.” Specific lessons noted included taxi, take-off, flight controls, Bernoulli’s Principle, instrumentation, and the phonetic alphabet. Regarding the instrumentation session, one counselor remarked, “the discussion of the gauges enhanced the children’s understanding of detailed flight terminology.”

Comparable to simulator activities, rocket building and launching were frequently mentioned. As one counselor remarked, “rocket building helped with reading instructions and motor skills and children liked this activity.” Likewise, the incorporation of air traffic control-style communications was explicitly mentioned as a positive aspect of simulation sessions. This was a feature that was introduced during the third week of the second summer camp. One counselor stated, “Once they got involved with Air Traffic Control (ATC), they seemed more focused and less inclined to fly off or intentionally crash.” Similarly, games were mentioned as something the counselors liked. Suggestions for improving the program included developing challenges of increasing complexity, additional worksheets, lessons, and the use of more children’s games.

The two aviation undergraduate counselors were asked to complete an additional reflection on aviation activities. Both commented that, in addition to the simulators, worksheets were the most compelling aspect of the aviation camp modules:

> The simulators paired with the worksheets were the most effective in teaching the basics of flight.
>
> The most effective aspect of the aviation module was worksheets. Without the worksheets, planning out sims and finding a universal way to teach the kids would be more difficult.

When asked about the value of the aviation component of the summer camp, the aviation counselors offered complementary, yet distinct reflections. One spoke to the developmental knowledge, skills, and abilities provided. For this person, the aviation program, “Improves listening and motor skills. Children also learn basic physics and other subjects while having fun. They also came up with creative solutions, and it engaged their imagination.” The other counselor spoke to the broader impact such an encounter provided the children, “The value of the aviation module is indescribable. It showed the kids a new world with various possibilities for them.”

Regarding what they learned about themselves as a result of their participation, both wrote about the need for patience when working with children. Both counselors reflected on connecting with the children. One focused on the need to develop a varied teaching style to connect with different children, “I learned how to adapt to each child’s learning pace and find creative visuals to teach the kids.” The other spoke to the challenge of maintaining focus during difficult times with the children, “they also liked learning but tried to act as if they did not.” This person concluded, “It was neat how the children grasped new concepts and knowledge and how behaviors changed during the progression of camp.”

Observations

The researchers shared and reflected upon their individual observations within the broader context of the data collected from each group of participants. A number of themes emerged that appeared to expand and further nuance the results achieved through analysis of participant provided data. These observations are discussed below in terms of active learning, simulator use, and one-on-one interactions.

Active learning. Lecture and other, more passive activities were a challenging aspect of the program. The youth showed more interest in events that were higher energy. For example, the youth seemed more interested in launching rockets than building them. Even with hot temperatures outside, the patience and interest of the youth were consistently greater during the rocket launch activities. Moreover, many appeared to be enthusiastic to see how the rocket they built flew.

It was somewhat surprising that some campers shunned the rocket building activity. At the extreme, two campers initially refused to participate in building a water bottle rocket. These campers were given a choice to move to an adjacent room and sit or read quietly. One camper observed the others working on their rockets and soon decided to rejoin the activity. The other camper maintained that they thought the activity was childish and did not participate. However, once they saw the rockets fly, they became quite engaged with the launching process. A few days later, when the group began to build Estes model rockets, that camper was attentive and engaged. In each case, the campers did not appear to have an adequate perception of how the activity would unfold. By allowing them the option to observe but not participate resulted in their re-engagement of the activity.

Understandably, the least favorite activities were presentations and worksheets. In 2018, rewards in the form of candy were offered as an incentive to participate and pay attention. The campers were told they would get candy if they answered questions correctly. Not surprisingly, even those who did not appear to be paying attention raised their hands to answer the questions and frequently answered correctly. In 2019, there were no such rewards, and most of the time, the campers did not volunteer to answer the counselor’s questions. However, when called on, most of the campers were able to answer correctly, even without the added incentive. Thus, in either case, it appeared to be a misconception that the campers were not paying attention to the lectures. Furthermore, over-reliance on gimmicks to increase participation may not yield the desired results. Understanding the attention span of the age group as well as the current techniques employed at the particular age level may have a more satisfactory outcome. A number of such approaches were observed during the study.

One such technique was limiting lectures in terms of length and material. Keeping lectures short and focused on a few key points appeared to be helpful in maintaining interest. Also, understanding that the campers may be paying attention even when it did not appear so seemed to bolster the counselors’ confidence with an activity. Another strategy that helped to maintain engagement was the addition of various games designed to help introduce a topic and reinforce learning. Two such games were *Thumbs Up* and *Simon Says*. Thumbs Up was developed to review the four forces of flight. The counselor called out one of the four forces: lift, weight, thrust, drag. The campers would respond to the counselor’s call-out by putting their thumbs up for lift, turn them down for weight, backward for drag, and point with their forefinger for thrust. If a camper indicated the wrong vector, they would sit down for the remainder of the round. Similarly, the counselors adapted Simon Says to help the campers practice the three degrees of freedom: pitch, roll, and yaw. A counselor would play Simon and direct the campers to perform an action on the control yoke, for example, “Simon says roll left” or “Pitch up.” If the camper performed the function without hearing, “Simon says,” they were out of that round of the game.

Implementing worksheets was a third strategy for maintaining direction, particularly when used in conjunction with simulator activities. Worksheets were developed by the collegiate flight training camp counselors and required campers to use the simulators to in various ways in order to complete tasks or answer questions. Campers would have to identify basic aerodynamic principles, operate control surfaces, recognize and interpret flight instruments, and the like. The worksheets were developed to be age-appropriate and to aid in the development of problem-solving and critical thinking skills. From the first effort, it was clear that when presented with a worksheet, the campers engaged the simulation activity with greater attention.

Simulator Use. It was not surprising that a great deal of interest and excitement surrounded opportunities to work with the flight simulators. Campers would ask to use them on days when aviation was not part of the camp schedule. However, similar to other activities in the program, it became apparent that simulator sessions were more effective when they were more closely tailored to the interests and abilities of the campers and had objectives they could achieve within a session. Activities that did not account adequately for the age group quickly lost interest and resulted in campers wandering off task. In addition to those noted above, a variety of techniques were implemented to maintain focus by providing age-appropriate challenges and goals for the campers to achieve. For example, basic aircraft control during taxi was introduced while concurrently working on airport markings and the phonetic alphabet and supplemented with games that reinforced the requisite knowledge for the activity.

During 2019, this gave way to a challenge for the campers to follow a set of instructions and taxi from one point on the airport to another. The activity did not include a flight component, and yet the campers maintained a fairly high degree of concentration as they worked to complete the task. Toward the latter stages of the camp, this was further supplemented by networking the simulators with an ATC station in a separate room. The campers used internet-enabled headsets to communicate with ATC. A counselor provided taxi and take-off clearances as well as radar vectors and other supporting instructions to help the participants navigate to a nearby landmark while utilizing proper communication techniques. The addition of “radios” to the simulation increased interest and maintained focus throughout the activity.

Working One-on-One. When able, campers and counselors were paired one-on-one. With the added attention, the campers developed a greater rapport and were more likely to listen to camp counselors, even outside of those sessions. During some sessions, not enough camp counselors were available to provide such focused attention. This was particularly detrimental during flight simulator activities where the shortage of counselors meant that the campers had to wait for direction and support. At times, this resulted in distraction and impatience. The on-line ATC activity alleviated this to some degree. The counselor in the other room performing the ATC role could monitor and provide direction almost simultaneously to multiple campers. This freed the in-room counselors to focus on campers who needed more attention. Additionally, the novelty of communicating via the headsets served to help maintain focus as the campers appeared to be more interested in following the directions provided over the radio.

Limitations

The results of this study are limited. The study was purposefully focused on providing an aviation experience to an underrepresented group. As a collective case study, the findings are inherently limited in terms of generalizability. It is hoped that the perspectives will be useful for the development of similar activities and will encourage additional research (Merriam, 2009). The results obtained would benefit from further research across other disciplines and populations. Questions that attempted to elicit camper preferences did not always provide enough specificity, even when coupled with counselor feedback and observations. Future studies may wish to consider follow-up questions to clarify what the campers liked or did not like.

Additionally, some of the responses to various survey questions appeared to be in response to other activities of the summer camp. Because there were a variety of topics presented during the camp, it is possible that some responses were referencing aspects of the camp other than the aviation modules. This is particularly true where questions did not explicitly refer back to aviation. Finally, while the results identified a number of strategies, evaluating best practices was not a focus of the study. It did not address the question of how such programs might support interest and academic performance in STEM-related subjects, nor can it predict the effect such a program might have on youth development.

Conclusions

The data collected from the campers and the camp counselors, and the observations of the researchers, all indicate that the perspectives and attitudes of the youth and counselors who participated in the program were decidedly positive. Twenty-three out of 25 youth participants responded that they liked aviation, and 22 would recommend the program to others. They found the camp to be a supportive environment and felt cared for. The children were engaged and motivated, even as they seemed at times to be distracted. The results suggest that the campers were connected to and engaged in the program.

Likewise, it appeared to the adults that the youth developed critical thinking skills and peer relationships; however, as this was not a primary focus of the study, additional research into critical thinking and OST programs may provide additional insight. Games, worksheets, age-appropriate challenges, and one-on-one supervision were effective in supporting lecture and simulator activities. The addition of on-line ATC was particularly effective at drawing focus on the planned activity. Overreliance on rewards did not appear to be as effective as identifying and implementing strategies that were more closely suited to the age and experiences of the participants. Given these outcomes, additional research into the educational benefits of the strategies identified would serve to advance understanding of their value. In particular, further investigation is needed to better understand the extent to which aviation programs may serve the development of critical thinking skills.

Given the outcomes of the study, the development of aviation programs with activities closely tailored to age-appropriate academic objectives is recommended. Almost half of the respondents indicated they would consider becoming pilots in the future, nine strongly so. The remaining were either not interested or were neutral. It was interesting that the responses of those who did not want to become a pilot in the future were strongly so. While this outcome appears to be consistent with the age of the campers and a normal diversity of interests, there may be additional explanations for the response rate. Questions surrounding access to the idea of such a career track as well as financial, educational, and other barriers remain. Additional research into this area would provide a greater understanding of the motivations this population of young people carries and the barriers they face. Regardless of career aspirations, longitudinal studies that follow the progression of youth engaged in such programs may provide insight into long-term benefits, including how such programs may support and encourage involvement and persistence in educational pursuits, particularly as they relate to STEM disciplines.

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Assessing Cultural Drivers of Safety Resilience in a Collegiate Aviation Program

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Organizational safety resilience is a key factor in sustaining an effective safety management system (SMS) in high-reliability organizations (HROs) such as aviation. Extant research advocates for monitoring, assessing and continuously improving safety in an organization that has a fully-functional SMS. Safety resilience provides a buffer against vulnerabilities. Extant research also suggests a paucity in terms of a measurement framework for organizational safety resilience in collegiate aviation operations. A quantitative approach using Reason's safety resilience concept (Reason, 2011) is used to assess organizational safety resilience in a collegiate aviation program with an *active conformance* SMS accepted by the FAA. A sample of 516 research participants responded to an online survey instrument derived from Reason (2011). Structural Equation Model (SEM)/Path Analysis (PA) techniques are used to assess models that measure the strength of relationships between three cultural drivers (Commitment, Cognizance, Competence) of safety and safety resilience. There were strong significant relationships between these cultural drivers and safety resilience. Path analysis suggests that Commitment significantly mediates the path between Cognizance and Competence and highlights its important role in sustaining safety competencies. There were significant differences in the perceptions of safety resilience among top-level leadership, flight operations and ground operations. Flight operations and ground operations had higher mean scores on safety resilience than top-level leadership. Study provides a validated model of safety resilience that is essential for SMS improvements in collegiate aviation programs. Future studies will utilize this safety resilience model to assess other collegiate aviation programs in various phases of SMS implementation, airlines, and air traffic control operations.

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A rapidly changing technological workspace and corresponding requirements for acceptable-levels of safety in the aviation operational environment should be complemented by a proactive safety culture and organizational resilience. Safety resilience is a characteristic of an organization that has good safety procedures and practices which enable it to have greater resistance to incidents and accidents, as well as being able to cope better when they occur (Hollnagel, Paries, Woods, & Wreathall, 2011).

Proactive safety culture and safety resilience are key enablers for effective safety management systems (SMS) implementation and continuous improvement. Under normal conditions a positive safety culture is known to be reflected in proactive behavior and to serve as indirect indicator of organizational resilience (Schwarz, Wolfgang, & Gaisbachgrabner, 2016). This acceptable–level of safety requirements has necessitated a global advocacy for a shift from prescription-based safety management among aviation certificate holders to a performance based one to enhance operational flexibility and resilience (ICAO, 2013a; ICAO, 2013b).

Improving operational capabilities while ensuring a commensurate level of acceptable safety within a resilient culture is one of the key attributes of a Safety Management System (SMS). SMS is a formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk (FAA, 2015a). Collegiate aviation programs are not under regulatory mandate by the Federal Aviation Administration (FAA) to have an SMS. However, SMS is required by certificate holders such as Part 121 airlines (Electronic Code of Federal Register. Part 5, 2015). Some collegiate aviation programs have adopted the voluntary SMS initiative promoted by the FAA due to the immense benefit derived in terms of proactive risk management and building of a resilient safety culture in their operations (Adjekum, 2014).

Despite strenuous efforts to ensure an acceptable-level of safety in operations, there are still un-anticipated safety risk in high reliability organizations (HROs) which are hazardous organizations that operate almost error-free over long periods of time (Roberts, 1990). HROs are entities that efficiently perceive changes in its environment and responds appropriately to them and where accidents can be prevented through good organizational design and management (La Porte, 1996; Weick & Sutcliffe, 2007). Examples of HROs are nuclear industry, oil and gas industry and aviation. Programs that provide aviation training at the collegiate level can be classified under generic aviation HROs. With the challenges of controlling these un-anticipated safety risks, HROs should make every effort to build a safety resilient culture to sustain a proactive safety system and prevent undesired safety events from re-occurring (Hollnagel, Woods & Leveson, 2006).

Safety resilience ensures that HRO’s that operate in high risk environment such as aviation training have robust safety defenses and controls to minimize their vulnerability to adverse safety events. The topic of safety resilience within the aviation operational environment has been researched in extant literature (Akselsson, Koorneef, Stewart & Ward, 2009; Heese, 2012; Hollnagel, 2009; Hollnagel, 2014; Reason, 2011). The findings of these studies advocate for robust and resilient safety systems as the next level in an organizational that has a fully functional SMS program in place.

Reason (2011) provides a conceptual model of a safety resilience engine that drives an organization's safety program within a cultural context. Reason hypothesizes that these safety cultural drivers (3Cs - commitment, competence and cognizance) are related to resilience in an SMS program. An SMS that has reached the highest level of functionality and has all the various components established, validated and effective needs to be continuously monitored and improved due to changes in the operational environment (Schwarz & Kallus, 2015; Adjekum, 2017). Under the voluntary SMS program adopted by some collegiate aviation programs in the U.S., the level of a*ctive conformance* is attained when the Federal Aviation Administration (FAA) acknowledges full implementation of the certificate holder's SMS. The certificate holder is expected to use organizational factors to build a strong safety resilience culture aimed at reducing vulnerabilities (FAA, 2015b).

Changes such as financial status, national policies, quality of human resources, leadership attrition and high–tempo operational activities may induce safety vulnerabilities (reductions in the margins of safety that the safety controls can tolerate) (FAA, 2015a; Adjekum, 2017). Safety resilience ensures that operational vulnerabilities due to increased activities are consistently identified and managed. In the unfortunate scenario of an adverse safety event, an organization that is resilient may still recover and operate effectively.

Research Problem

Extant studies on safety resilience in aviation have been mostly limited to commercial aviation operations and air-traffic control management (Akselsson et al., 2009; Heese, 2012; Hollnagel, 2009; Hollnagel, 2014; Reason, 2011). Specific studies on safety resilience in general aviation such as collegiate flight training seems limited if not completely missing in the United States. A search in extant literature suggests paucity in studies that assess the relationships between the cultural drivers of safety (3Cs) and organizational safety resilience in a collegiate aviation program with an *active conformance* SMS in the United States.

Research Objectives

Studies identifying areas of safety weaknesses and improvements in SMS of collegiate aviation programs have been highly recommended (Adjekum, 2017). Determining the levels of organizational safety resilience in an SMS accepted by the Federal Aviation Administration (FAA) as being in the *active conformance* status can be beneficial to a collegiate aviation program. This study aimed at determining survey instrument items that loaded strongly on cultural drivers of safety using Confirmatory Factor Analysis (CFA). Measurement models that links these cultural drivers of safety and their underlying measured items were assessed for goodness-of-fit.

Another objective was to assess the strength of relationships between the cultural drivers of safety and organizational safety resilience in a collegiate aviation program using Structural Equation Model (SEM) techniques. A full structural model that showed the relationships between the 3Cs and organizational safety resilience was proposed. Reason (2011) suggested that there were also intrinsic relationships among the 3Cs. Mediation/ Path analysis (PA) was used to explore these relationships. Finally, variations in perceptions of organizational safety resilience in the collegiate aviation program among demographic variables such as age, functional groups and gender were analyzed.

Research Questions

1. What is the effectiveness of measurement models of Reason's cultural drivers of safety resilience "Commitment, Cognizance and Competence" in a collegiate aviation program with an *active conformance* SMS?
2. What is the strength of relationships between the variables Commitment, Cognizance and Competence and the latent construct organizational safety resilience in a collegiate aviation program with an *active conformance* SMS?
3. What is the strength of relationships between variables Cognizance and Competence when mediated by Commitment in a collegiate aviation with *active conformance* SMS program?
4. What is the variation in perceptions among demographic variables Age, Functional Groups and Gender on the three cultural drivers of safety in a collegiate aviation program with an *active conformance* SMS?

Literature Review

Vulnerabilities in safety defenses of any organization can precipitate errors and failures which can have adverse effects on the functional capabilities of such organizations. These vulnerabilities can cause tragic accidents, destroy value, waste resources, and damage reputations (Coombs, 2007; Yu, Sengul & Lester, 2008). Many organizations systematically strive to avoid failure, particularly when the consequences are severe, and some HRO's are able to achieve remarkably error-free operations even in the face of challenging conditions (Weick & Sutcliffe, 2007).

Extant research in safety science suggests that accident rates in "ultra-safe" systems (such as commercial aviation and nuclear power) seem to be asymptotic at around five disastrous accidents per 10^{-7} safety units of the system (Amalberti, 2001). These findings suggest that even for safety-conscious and safety-critical organizations, there may be challenges to eliminate all failures. This supports the assertions that accidents are inevitable in complex, tightly coupled systems (Leveson, Dulac, Marais & Carroll, 2009; Perrow, 1984). That is why the interlink between safety resilience and safety management becomes very relevant to be able to proactively identify vulnerabilities and veritable management practices that shapes the cultural drivers of safety in such organizations (Reason, 2011).

Reason (2011) posits that the engine that drives any safety initiative in an organization is primed by the cultural core of an organization. Within the core are three driving forces namely; commitment, competence and cognizance. Commitment has two components: motivation and resources. Motivation hinges on whether an organization strives to be a domain model for good safety practices, or whether it is content merely to keep one step ahead of regulatory sanctions. Resources on the other hand deals with the financial and human capital (caliber and status of those people assigned to direct the management of system safety) in the organization.

A highly resilient safety program in an organization requires the technical competence necessary to achieve enhanced safety. Paries, Valot and Deharvenght (2018) using a generic taxonomy of safety management modes, within the French Air Navigation Service Provider (ANSP), found out that formal SMS implementation did not include many of the HROs features. However, the researchers also found out that in the real “life” of the organization, particularly at operational levels (control rooms and maintenance units), most of the HROs features could be observed as informal work or skills. Paries et al. (2018) further suggests some defining technical competencies of HROs as follows:

a. Identification of hazards and safety-critical activities.
b. Preparations and contingencies for crises and linking of crisis plans closely to business-recovery plans.
c. Ensuring the defenses, barriers and safeguards possess adequate diversity and redundancy.
d. Creating a structure of the organization that is sufficiently flexible and adaptive.
e. Ensuring the right kind of safety-related information is being collected and analyzed appropriately.
f. Getting this information disseminated and making sure it is acted upon.

Cognizance is the final driver within the cultural core that determines the need for an organization to be adequately conscious of the dangers that threaten its activities and understand the true nature of the struggle for enhanced resilience. An organization must always be in state of intelligent wariness even in the absence of bad outcomes (Reason, 2011; Hollnagel, 2014). This is the very essence of a proactive safety culture. Cognizance ensures that the primary goal of safety management which is, maintaining a region of the safety space associated with the maximally attainable level of intrinsic resistance, is achieved (ICAO, 2013a).

In their research on resilience within the healthcare industry, Smith and Plunkett (2019) posits a link between cognizance and competence. Their study analyzes the distinction between ‘work as imagined’ and ‘work as done’ as originally suggested by Hollnagel (2009). ‘Work as imagined’ assumes that if the correct standard procedures are known, understood and followed, safety will follow as a matter of course. However, staff at the ‘sharp end’ of organizations know that to create safety in their work, variability is not only desirable but essential. This positive adaptability within systems that allows good outcomes in the presence of both favorable and adverse conditions is termed resilience. They further argue that clinical and organizational work can be made safer, not only by addressing negative outcomes, but also by fostering excellence and promoting resilience through non-punitive safety reporting.

Even within industries where there are formally established safety practices such as aviation and the offshore oil industry; practical skills, support from colleagues, the creation of ‘performance spaces’ and flexibility in problem-solving (all rooted in the informal elements of work) are important in maintaining safety (Hollnagel, 2009). Oliver, Calvard, and Potočnik

(2017) in a study on cognition, technology, and organizational limits suggest that HRO's may hold important lessons for other organizations as they tread a path between developing capabilities for safety resilience aimed at avoiding errors and subsequent failures.

They also suggest that controllers of complex systems, whether they are pilots or executives, run the risk of becoming insulated from the systems that they oversee. For top-level management executives, this might result in separation from front-line operations, such as when responsibilities are delegated to units who largely follow established protocols, resulting in organizational mindlessness (Sutcliffe, Vogus & Dane, 2016). This is where commitment needs to mediate the relationship between cognizance and competence at all levels.

Oliver et al. (2017) further found out that vulnerabilities in highly complex systems are sometimes not matched by the organization's ability to organize and control them in the face of most conceivable conditions, let alone unpredictable ones. As organizations and systems grow in scale and complexity, the issue of how to develop an organization to handle unexpected and extreme events grows ever more challenging.

The implication is that top-management executives should continuously monitor and develop improvement strategies to respond appropriately to unusual conditions. The cultural drivers, namely; competence by top-level management and cognizance at all levels within the organization is paramount for ensuring the organizational safety goal of resilience. Finally, the assessment of the strength of relationships among the cultural drivers of safety is suggested by Reason (2011) as the SMS becomes fully-functional and there is a constant shift in safety space between vulnerabilities and resilience.

Methodology

Research Design

A quantitative research design involving an online and anonymous survey was used to elicit the perceptions of respondent on scale items related to safety resilience in a collegiate aviation program. Likert scaled items (1= strongly disagree to 5 = strongly agree) were adapted from Reason's attributes of a proactive safety resilient organization (Reason, 2011) and a face /content validity review was done by two SMS subject -matter experts (SME) with combined working experience of almost 40 years as SMS training facilitators, researchers and collegiate aviation faculty members. Based on recommendations from the review, some minor changes in survey items sequencing were done.

The cultural driver *Commitment* has 9 items with "Personnel proactively discuss safety-related issues whenever the need arises" being an example of construct item. *Competence* has 7 items and an example of construct item is "There are standard operating procedures for recovery from errors recognized which are reinforced by training." The third cultural driver *Cognizance* has 7 items and an example of construct item is "There are comparable procedures in place to ensure safe transitions from the normal to emergency status." Details of survey items used for analysis is shown in Appendix A. A sample size greater than 300 was recommended as expedient to obtain meaningful fit of the measurement models based on Kline (2005) SEM recommendations using model parameters.

Sampling and Survey Dissemination

A population of about 1850 comprised of students, faculty and supporting staff of a collegiate aviation program in a large university located in the North-Western part of the U.S. was sampled in this study. A convenience sampling approach was used to send an anonymous online survey link via email to participants (aviation students, certified flight instructors, faculty, maintenance, dispatch and top-level management) in the aviation program that also has an *active conformance* level SMS accepted by the FAA.

The introduction of the survey had the research purpose, objectives and contact information about the researchers. It also had a digital consent which provided the option to accept or decline participation. For those who consented to participate, a hyperlink was provided on completion of survey directing them to another site where participants could submit their emails to win a $20 gift card in a random draw. The online survey was open for a three-week period in the Fall semester of September 2019.

Data Collection and Preliminary Data Analysis

Relevant demographic data to assist in understanding the population was collected and highlighted in this paper and will also be used in another study aimed solely at demographic variations on safety resilience. At the end of the survey response period, the data was transferred from the Qualtrics® survey site into IBM SPSS® version 26 software for preliminary screening. The data was screened for multivariate normality using a combination of visual means such as normality plots of histogram, kurtosis/skewness values and N-N plots (Fields, 2018). There were no severe indications of non-normality or outliers in data that warranted transformations. IBM SPSS® 26 analysis function for “pair-wise deletion of missing data” was used for the missing data analysis. The full-information maximum likelihood approach using the IBM AMOS® V25 was used for model assessments, strength of relationships between measurement scale variables (items), and the cultural drivers of safety (Enders & Bandalos, 2001).

Instrument Reliability, Construct Validity, and Goodness-Of- Fit Indices Criteria

The reliability of scale items underlying factors representing the cultural drivers that generated acceptable fit for CFA models was determined. The outcomes from CFA models were used to assess the reliability, convergent validity, and discriminant validity. A Cronbach’s alpha (α) value of 0.7 or higher indicates good reliability of measured items (Nunnally, 1978) and SPSS 26 was used to determine the reliability. Commitment ($\alpha = .85$ for 7 items) and Competence ($\alpha = .80$ for 6 items) had good reliability. The factor Cognizance had a fair reliability after the first analysis ($\alpha =. 54$ for 5 items) and the reliability improvement function of SPSS was used to delete the items cog 6 and cog 7. The next iteration improved the reliability ($\alpha = .70$ for 3 items) to an acceptable level.

The average variance extracted (AVE) method was used to assess the convergent validity (Fornell and Larcker, 1981). The AVE for commitment (.43), cognizance (.42) and competence (.42) were all below the criteria suggested by Fornell and Larcker (AVE > .50). This result suggests weak evidence of convergent validity. Using the Chin (2010) and Henseler & Sarstedt (2015) recommendations of checking for cross-loading in the correlation matrix, some evidence of discriminant validity also called "item-level discriminant validity" was observed. The correlation matrix did not show any form of cross-loading of items among the constructs.

According to Gefen and Straub (2005), an item should be highly correlated with its own construct, but have low correlations with other constructs in order to establish discriminant validity at the item level. Hair, Ringle & Sarstedt (2011) recommends that the cut-off values of factor loadings should be higher than .70.in that case. The evidence of weak convergence validity should be taken into consideration when interpreting the results despite the evidence of discriminant validity.

The items in each factor were summed up and used as indicator variables to assess the relationship between cultural drivers and the over-arching concept of safety resilience. A model containing all the individual measurement models was assessed for fit. Finally, the strength of relationships and levels of interaction among the three cultural drivers were also assessed using causal path analysis and Hayes Process V.3.4 in SPSS (Fields, 2018). A full structural model showing relationships between cultural drivers of safety and safety resilience was proposed. Annex A has all the measurement items retained after the reliability and validity assessment. Annex B has details of correlation matrix highlighting lack of cross-loading among construct items.

A large class of omnibus tests exists for assessing how well measurement models matches observed data. The chi-squared (χ^2) is a classic goodness-of-fit measure to determine overall model fit. However, the chi-squared is sensitive to sample size, and it becomes difficult to retain the null hypothesis as the number of cases increases (Kline, 2005). The χ^2 test may also be invalid when distributional assumptions are violated, leading to the rejection of good models or the retention of bad ones (Steven, 2002; Brown, 2006; 2015).

Another commonly reported statistic is the Root Mean Square Error of Approximation (RMSEA). A recommended value of 0.05 or less indicates a close fit of the model in relation to the degrees of freedom (Brown, 2006; 2015). Another test statistic is the Comparative Fit Index (CFI) that evaluates the fit of a user-specified solution in relation to a more restricted, nested baseline model, in which the covariance among all input indicators are fixed to zero or no relationship among variables is posited (Brown, 2006).

The fit index CFI ranges from 0, for a poor fit, to 1 for a good fit. Finally, the Tucker-Lewis Index (TLI) is another index for comparative fit that "includes a penalty function for adding freely estimated parameters" (Brown, 2006, p. 85). Other indices are the Normed Fit Index (NFI) and Incremental Fit Index (IFI). Hu and Bentler (1999) provided rules of thumb for deciding which statistics to report and choosing cut-off values for declaring significance. When RMSEA values are .06 or below, and CFI and TLI are .95 or greater, the model may have a reasonably good fit. In this study, the TLI, $\chi 2$, RMSEA, CFI, NFI and IFI were reported for measurement models. If the model fit was not satisfactory, a post hoc analysis was performed to modify the CFA model to make it better fit. Items with high error covariance were eliminated as necessary.

Results and Findings

There were 519 responses at the end of the survey period. Out of the 519 responses, 516 respondents consented to undertake the survey (99.42%) and 3 declined (0.58%). Details are outlined in Table 1. Out of the 516 positive responses, only 481 respondents provided details about their functional personnel group. The details of the demography are outlined in Table 2.

Table 1
Consent to Participate in Anonymous Survey

Answer	Percentages (%)	Count
Yes	99.42%	516
No	0.58%	3
Total	100%	519

Table 2
Functional Group of Respondents

Functional Groups	Percentages (%)	Count
Flight Operations (Aviation Students & Flight Instructors)	76.50%	368
Top-level Management/Faculty (Administrative)	9.56%	46
Operations Support Staff (Maintenance/Dispatch/Ground)	13.94%	67
Total	100%	481

There were 420 responses to this item on the survey and the demographic layout suggest that majority of the student respondents to this item were juniors (29.05%). The breakdown of responses, counts and percentages are outlined in Table 3.

Table 3
Student Academic Group

Answer	Percentages (%)	Count
Freshman	15.00%	63
Sophomore	27.62%	116
Junior	29.05%	122
Senior	23.81%	100
Graduate	4.52%	19
Total	100%	420

Respondents were asked to provide details about their highest flight certification and ratings and the result suggest that majority of respondents were private pilot certificate holders (46.90%). Among the other responses were participants with Airline Transport Pilot (ATP) certification (7), Airframe & Power Plant (A&P) ratings (5), 1 respondent with Airframe and Power Plant with Inspection Authorization (A&P IA) and 10 non-pilots. Figure 1 outlines details of the demographic lay out.

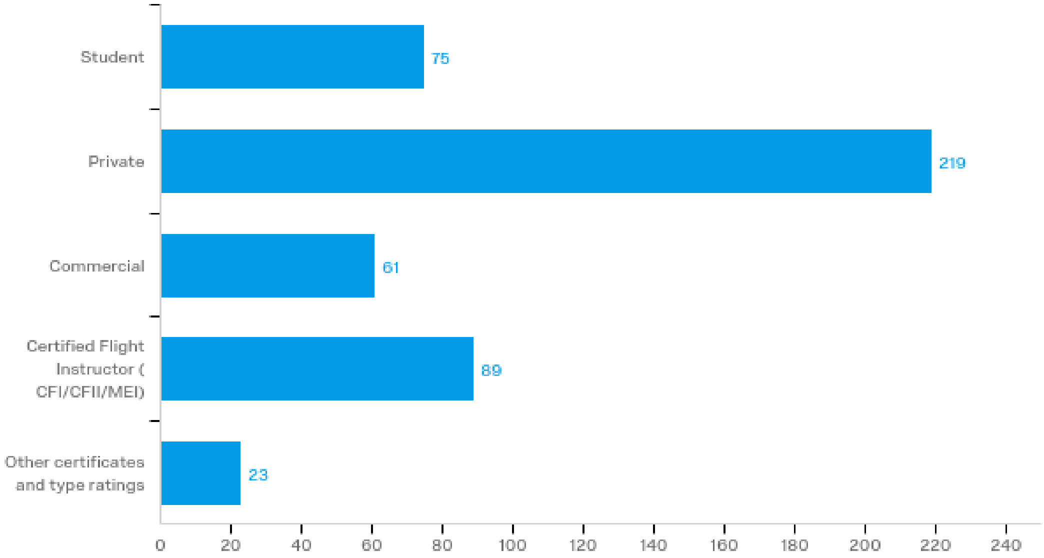

Figure 1. Highest Flight Certificate/Ratings Held

Age and Gender

Respondents were asked to provide their age as part of this study. There were 470 responses and results show a mean value close to 23 years (M =22.94, SD = 7.944) with a median of 20 years. Result also showed that the modal class was the 20-year old respondents and the highest age was 67 years. There were 396 male respondents (76.7%) as compared to 120 female respondents (23.3%). Table 4 shows the descriptive statistics for *Age* variable.

Table 4
Age distribution of Participants

Item	Value
Mean	22.94
Median	20.00
Mode	20.00
Std. Dev.	7.944

Question One
What is the effectiveness of measurement models of Reason's cultural drivers of safety resilience "Commitment, Cognizance and Competence" in a collegiate aviation program with an active conformance SMS?

A first-order CFA was conducted to evaluate the strength of relationships between a set of seven measurement items and the latent construct cognizance. A measurement model is normally used to examine the relationships between the observed variables and the latent factors. CFA allows researchers to test hypotheses about a factor structure (e.g., factor loading between the first factor and first observed variable). Unlike an Exploratory Factor Analysis (EFA), a CFA is theory-driven and produces several goodness-of-fit measures to evaluate the model. However, it does not calculate factor scores (Brown, 2006; 2015).

A five-item measurement model with good fit indices for cognizance was obtained after the initial seven-item model did not yield a good fit. A post-hoc modification using the Modification Indices (MI) function in AMOS recommended the addition of a covariance to the error terms of items cog6 and cog7. The items cog 4 and cog5 were deleted due to extremely low loadings and their adverse effect on fit indices. The final measurement model had good fit; χ^2 (4, *N*= 516) = 7.991, CMIN/DF = 1.998, *p* = .092, NFI = .971, IFI = .985, TLI =.943, CFI = .983, RMSEA = .044 (.000 - .088). Figure 2 shows the measurement model and Table 5 shows details of the factor loadings and squared multiple correlations (SMC or R^2). All β are significant to .000 level.

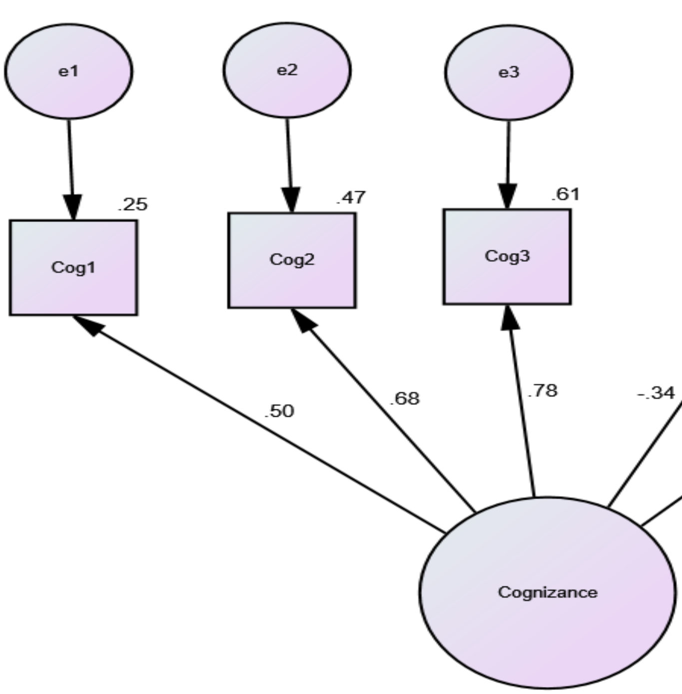

Figure 2. Measurement model of Cognizance

Table 5
Standardized Regression Weight and Squared Multiple Correlation of Cognizance

Measurement Item	(β)	R^2
Cog 1	.504	.252
Cog 2	.683	.466
Cog 3	.781	.610
Cog 6	-.336	.113
Cog 7	-.220	.048

Note: All beta values are significant to p < .001 level

A final seven-item model with the best fit indices was obtained for the factor Commitment after various competing models were assessed and post-hoc iterations were done using MI and Reason’s theoretical framework. Figure 3 shows the measurement model and Table

6 shows details of the factor loadings and squared multiple correlations (SMC or R^2). Details of the competing models are outlined in Table 7.

Table 6

Standardized Regression Weight and Squared Multiple Correlation of Commitment

Measurement Item	(β)	R^2
Comm 1	.695	.483
Comm 2	.618	.383
Comm 3	.701	.500
Comm 4	.644	.415
Comm 5	.736	.541
Comm 6	.561	.315
Comm 7	.622	.387

Note: All β are significant to $p < .001$ level

Table 7

Goodness-of -Fit Indices for Commitment

Iteration	Chi Square (X^2)	NFI	IFI	TLI	CFI	RMSEA
Model 1	χ^2 (0, N= 516) = not computed, CMIN/DF = not computed, p = not computed	.929	.944	.887	.943	.080 (.060 -.10)
Model II	χ^2 (13, N= 516) = 51.520, CMIN/DF =3.963, $p < .001$ (Covary e6/e7)	.939	.954	.898	.953	.076 (.055 -.098)
Model III	χ^2 (12, N= 516) = 40.832, CMIN/DF = 3.403, $p < .001$ (Covary e6/e7; e1/e2)	.952	.965	.918	.965	.068 (.046 -.092)
Model IV	χ^2 (11, N= 516) = 40.832, CMIN/DF = 1.937, $p = .030$ (Covary e1/e2; e4/e5; e6/e7)	.975	.988	.968	.987	.043 (.013 -.069)

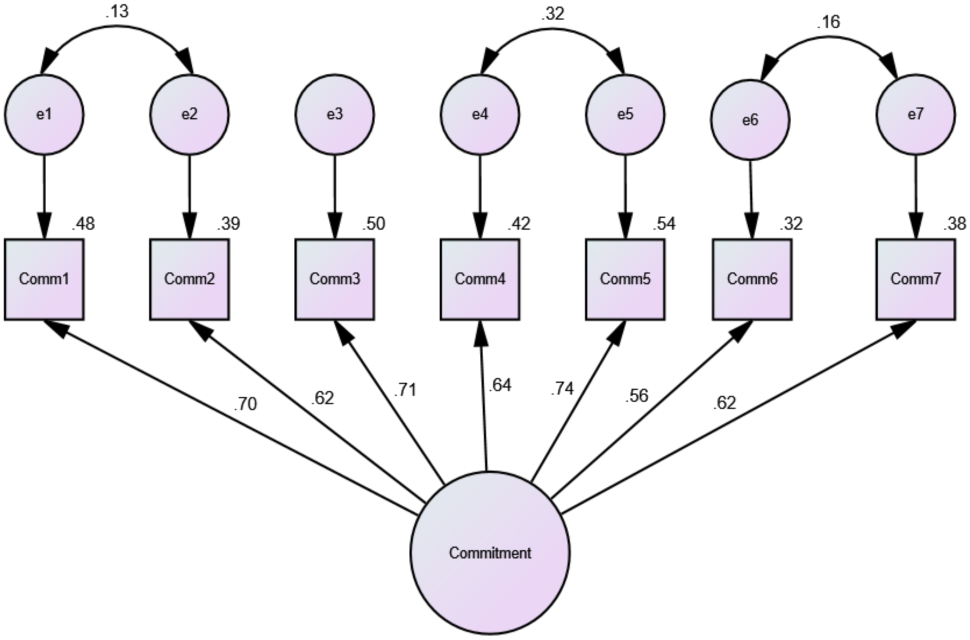

Figure 3. Measurement Model for Commitment

A final six-item model with good fit indices; χ^2 (9, *N*= 516) = 8.849, CMIN/DF = .983, *p* = .451, NFI = .983, IFI = .995, TLI =.997, CFI = .998, RMSEA = .001 (.000 - .049) was obtained for the factor Competence. There was no need for any post-hoc iterations using MI and Reason's theoretical framework. Figure 4 and Table 8 shows the measurement model and values of β and R^2 respectively.

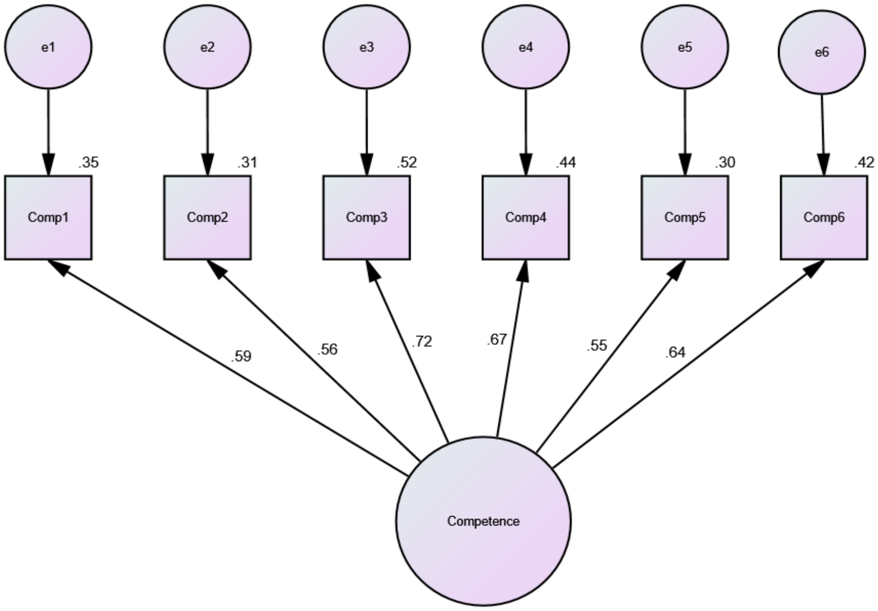

Figure 4. Measurement Model for Competence

Table 8

Standardized Regression Weight and Squared Multiple Correlation of Competence

Measurement Item	(β)	R^2
Comp 1	.591	.350
Comp 2	.555	.308
Comp 3	.724	.524
Comp 4	.665	.448
Comp 5	.548	.300
Comp 6	.644	.415

Note: All β are significant to $p < .001$ level

Question Two

What is the strength of relationships between the variables Commitment, Cognizance and Competence and the latent construct organizational safety resilience in a collegiate aviation program with an active conformance SMS?

Scale items underlying each cultural driver of safety with good reliability and validity were summed up to produce measured variables. The strength of relationships between these measured variables (commitment, competence, cognizance) and latent construct safety resilience were assessed using SEM/PA. The result suggests a significant predictive relationship between measured variables and the latent construct safety resilience. A full structural model that establishes the relationships between the cultural drivers of safety and the over-arching construct safety resilience had an acceptable fit; χ^2 (98, N= 516) = 375.877, CMIN/DF = 3.240, p = .000, NFI = .840, IFI = .893, TLI =.841, CFI = .881, RMSEA = .059 (.050 - .073). Figure 5 shows the full structural model.

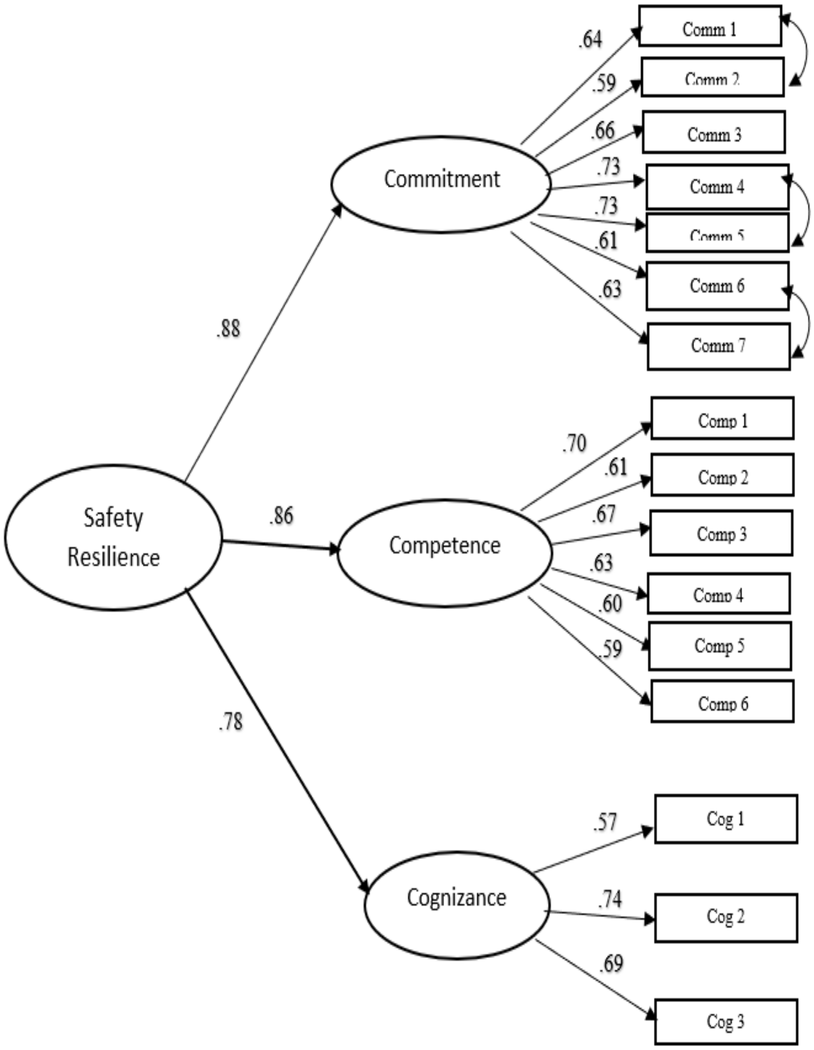

Figure 5. Final Structural Model of Relationships between 3Cs and Safety Resilience

The results from Figure 5 show that commitment and competence had the highest standardized regression weight of .88 and .86 respectively. Cognizance had the lowest standardized regression weight of .78. All of these were significant at p = .000. The SMC values and the standardized regression weight for all three cultural drivers are shown in Table 9. The results suggest that when safety resilience goes up by 1 standard deviation, there is a corresponding increase of .88 standard deviation in commitment. A unit standard deviation increase in safety resilience produces a corresponding .86 standard deviation in competence and .78 standard deviation in cognizance respectively. The R^2 value of commitment suggests that about 77% of the variances in commitment can be explained by predictors in the measurement model of commitment.

Table 9
Standardized Regression Weight and Squared Multiple Correlation of Safety Resilience

Factor	(β)	R^2
Commitment	.876	.767
Competence	.862	.743
Cognizance	.789	.623

Note: All β are significant to p< .001 level

Question Three
What is the strength of relationship between variables Cognizance and Competence when mediated by Commitment in a collegiate aviation with active conformance SMS program?

The PROCESS Version 3.4 for SPSS 26 (Fields, 2018) with bootstrap corrected accelerated (BCa) value of 5000 was used for a mediation analysis to assess the strength of relationships when commitment serves as a mediating variable between cognizance and competence. This analysis was based on Reason's suggestion that there exist intrinsic relationships among the 3Cs. It also aimed at exploring the potential mediating role of commitment in the relationship between cognizance (awareness) and competence of personnel in a collegiate aviation SMS environment.

The exogenous variable was cognizance and the endogenous variables were commitment and competence. The first model suggests a significant direct path between cognizance [β = .69, t (334) = 17.43, *p* = .000, 95% BCa (.559 - .701)] and competence. The model summary was [*F* (1, 334) = 303.64, *p* < .001, R^2 = .48] and shows about 48% of the variances of commitment is explained by cognizance.

The path between cognizance [β = .31, t (333) = 6.58, *p* = .000, 95% BCa (.211 - .392)] and competence was significant. The path between commitment [β = .54, t (333) =11.62, *p* = .000, 95% BCa (.485 - .823)] and competence was also statistically significant. The model summary [*F* (2, 333) = 270.78, *p* < .001, R^2 = .62] shows about 62% of the variances in competence can be explained by cognizance and commitment.

The standardized indirect effect of cognizance on competence was 0.375. Due to the indirect (mediated) effects of commitment on competence, when cognizance goes up by 1, competence goes up by about 0.38. The standardized indirect effect of cognizance on competence was higher than the standardized direct effect of cognizance on competence (.302) and validates the significant mediating role of commitment in the relationship. Figure 6 shows the causal path of the variables.

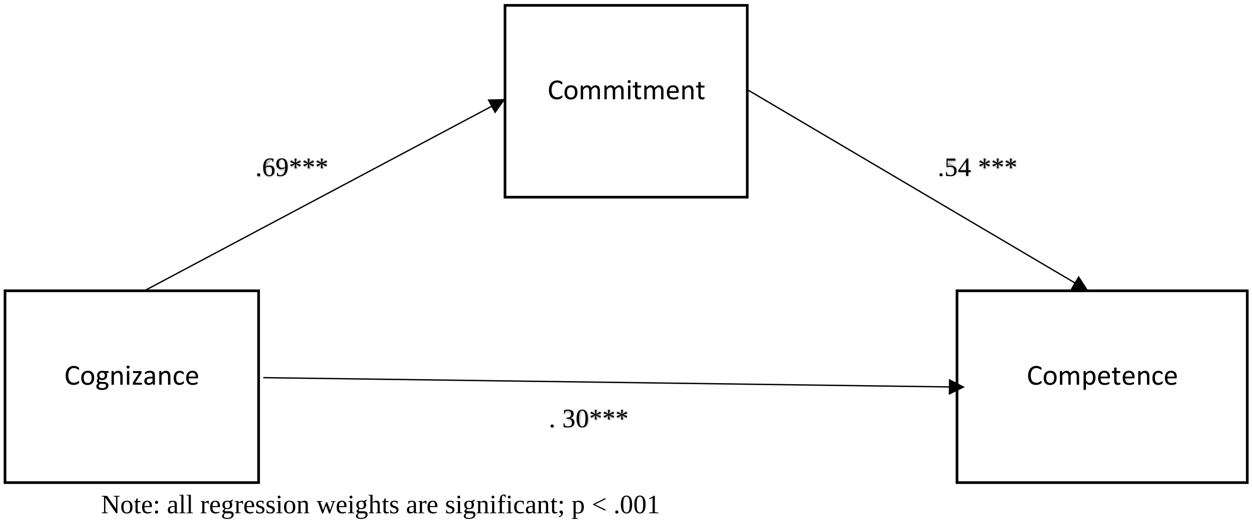

Figure 6. Causal Path Diagram of Cultural Drivers of Safety Interactions

Question Four
What is the variation in perceptions among demographic variables Academic Levels, Functional groups and Gender on the three cultural drivers of safety in a collegiate aviation program with an active conformance SMS?

A one-way Analysis of Variance (ANOVA) was conducted to determine if there existed significant differences in the perceptions on dependent variables (3C) among demographic variables academic levels, functional groups and gender. Only the functional group means yielded significance and post-hoc analysis was conducted. The results show that there were differences in the perceptions on commitment between the top-level management (M= 3.95, SE =.487) and flight operations (M = 4.76, SE = .308).

In terms of cognizance there was a significant difference between the perceptions of top-level management (M= 3.88, SE =.542) and flight operations (M = 4.74, SE = .339). There also existed a significant difference in the perceptions of the top-level management (M= 3.89, SE =.514) and operations support (M = 4.71, SE = .033) found in the cultural driver competence. An independent *t*-test was conducted to find out if there existed any significant differences in the mean of perceptions per gender. Result suggests no significant differences. Table 10 shows the results of the ANOVA for all three factors.

Table 10
ANOVA for Functional Groups

Factors	df1/df2	*F*	Sig.
Commitment	2, 336	3.840	.002
Cognizance	2, 349	3.155	.008
Competence	2, 336	4.452	.001

Note: p < .05 (2-tail)

Discussion and Conclusions

A structural model that assesses the strength of relationship between the cultural drivers of safety and the overall construct of safety resilience showed a good fit to the data. The results suggest that all the 3 cultural drivers have significant predictive relationship with safety resilience with almost 88% of the proportion of variances in commitment explained by safety resilience. About 86% of the variances in competence can be accounted for by safety resilience and about 78 % of the variances in cognizance accounted for by safety resilience. The results validate Reason (2011) concept of safety resilience and its relationship with cultural drivers of safety. The findings of this study corroborate Hollnagel (2014) and Akselsson et al. (2009) suggestions that safety resilience is an important element in the continuous monitoring and improvements of SMS in aviation.

Results also suggest that it is very important for collegiate aviation programs to constantly ensure that the mechanisms underlying resilience are assessed and improved. Cultural drivers such as competence, cognizance and commitment should have metrics that needs to be reviewed periodically during safety audits and SMS assessments to identify gaps and misalignments with desired outcomes. Competence requires effective training and mentoring and that leads to building the capacity of all personnel in the organization to be prepared and have contingencies for situations that has adverse impact on organizational missions and goals as posited by Adjekum (2017) and Stolzer & Goglia (2015).

The fact that cultural driver commitment significantly mediates the path between cognizance and competence is also intuitive. It shows that even though a robust awareness or educational program can be inherent in the SMS of a collegiate aviation, it may be inadequate as a stand-alone to ensure competence of personnel in safety resilience. It will require motivation from top-level management personnel, immediate supervisors and sometimes peers to enhance competence. The provision of adequate material, financial and moral support also enhances commitment to resilient practices.

Reciprocity in commitment is also required for personnel. Top-level management can provide time and money for personnel training and development to build knowledge and skills. These capacity-building resources ensures a safe working environment. Unfortunately, learning and application cannot be forced and personnel must be self-committed to learning and application of concepts to ensure competencies. Top-level management should provide empowered accountability that allows personnel to recognize hazards and the authority to mitigate the hazards. Such commitments also allow for work stoppage or deference to higher supervision when risk mitigation is above competencies.

The results show that the mean perceptions of top-level management were relatively lower for all three cultural drivers as compared to that of operations support and flight operations (aviation students and flight instructors). However, it was only the difference between the top-level management and operations support that was significant. This was quite surprising considering that in a previous study that assessed perceptual gaps in a collegiate aviation safety culture, top-level management had a better score than front-line personnel (Adjekum, 2017). The findings of the Adjekum (2017) study suggested that top-level management as resource providers, deemed their efforts at sustaining safety culture adequate which was not reflected by the perceptions of front-line personnel. In the present study, the assumption is that top-level management may be privy to resource constraints and prospective strategic initiatives that can pre-dispose aviation operations in their organization vulnerable, hence their seeming wariness as compared to front-line personnel.

An example could be un-anticipated financial disruptions and aviation industry market upheavals that can introduce vulnerabilities in aviation operations. To bridge the perceptual gaps related to the cultural drivers of safety resilience and SMS, transparency in information flow and periodic interaction between top-level management and front-line personnel is important. Overall, the perceptions on all three factors that underly safety resilience namely; commitment, cognizance and competence were good in the collegiate aviation program. It is highly recommended that periodic assessments of safety resilience are performed to make operations robust to such adversities.

Limitations and Generalizability of Findings

The findings of this study are based on perceptions of research participants from a single collegiate aviation program. Also, majority of the respondents to the survey were collegiate flight students and instructors who have relatively lower exposure to high tempo resilient practices experienced in commercial airline or military flight operations. They may also have minimal experiences with high impact safety occurrences that require higher levels of safety resilience to ensure business continuity. Therefore, results from this study should not be generalized across the aviation industry even though it can be relevant to other collegiate aviation programs of scope and complexity.

The weak evidence of convergence validity should be taken into consideration when making inferences on the findings in this study. It is recommended that future studies re-evaluate survey items for convergent validity. The uneven sample size of the functional groups should be considered when making inferences from the results of the ANOVA analysis. The majority of the respondents were young aviation students and flight instructors (M=23 years) and their perceptions on safety resilience and risk tolerability could have be shaped by psycho-social factors such as exuberance, peer-pressure and high self-efficacy (Thomson, Önkal, Avcioğlu & Goodwin, 2004; Adjekum, 2017; Wang, Zhang, Sun & Ren, 2018).

Implications of Study Findings for Research and Policies

This current study provides a veritable structural model with an acceptable fit and provides a framework for future studies on organizational safety resilience in aviation. These future studies recommended may include a comparative analysis of organizational safety resilience in collegiate programs with active conformance SMS status, those going through the voluntary process (active applicant and active participant) and those who are non-conformant (without an accepted SMS program).

Such a study could also provide a plethora of literature and additional assessment tools for organizational safety resilience in other certificate holders such as Airline Part 121, Air

Traffic Management, Airports and Unmanned Aerial Systems operations. Another significant benefit of this study is the capacity to assess operational vulnerabilities and strengthen safety resilience in collegiate aviation programs as part of continuous monitoring and improvements of SMS.

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Appendix A

Details of Measurement Items used in Assessment

Code	Measurement Item
Comm1	The safety mission statement is continually endorsed by top leadership's allocation of required resources (human/financial/technological)
Comm 2	Personnel proactively discuss safety-related issues whenever the need arises
Comm 3	Safety management issues are promptly attended to by top leadership without constraints
Comm 4	Procedures are in place within the organization to facilitate continuing professional development of personnel (new procedures/ techniques)
Comm 5	Procedures are in place to ensure that personnel under training attain pre-established competency standards
Comm 6	Trainees receive positive mentoring from instructors
Comm 7	Safety is recognized as being everyone's responsibility not just that of the safety management team
Comp 1	Top level leadership adopts a proactive stance towards safety
Comp 2	There are agreed standards for safety behaviors (acceptable/unacceptable)
Comp 3	Before any complex/unusual procedures, operational teams are briefed accordingly
Comp 4	Operational teams are debriefed after a task where necessary
Comp 5	Procedures backed by constant reminders helps to keep personnel knowledgeable in their job.
Comp 6	Useful feedback on lessons learned from safety events are quickly put into practice by personnel
Cog 1	Policies ensure that supervisory personnel are present throughout high-risk procedures.
Cog 2	There are standard operating procedures for recovery from errors recognized which are reinforced by training
Cog 3	There are comparable procedures in place to ensure safe transitions from the normal to emergency status (vice-versa)
*Cog 4R	Top leadership blame specific individuals who were involved in accident/incidents rather than improving failed system defenses
*Cog 5R	Personnel are not informed by feedback on recurrent error patterns in operations

R – Item was reverse coded; * Removed from final structural model due to low reliability

Appendix B

Cross-Loading Analysis of Correlation Matrix; Chin (2010) & Henseler et al. (2015)

	Commitment	Cognizance	Competence
Commitment	1		
Cognizance	.690	1	
Competence	.756	.678	1
Comm1	.710	.408	.453
Comm 2	.668	.407	.472
Comm 3	.734	.503	.538
Comm 4	.734	.553	.669
Comm 5	.715	.478	.532
Comm 6	.691	.457	.538
Comm 7	.690	.406	.456
Comp 1	.636	.521	.677
Comp 2	.550	.461	.659
Comp 3	.510	.526	.760
Comp 4	.497	.515	.733
Comp 5	.569	.410	.644
Comp 6	.468	.400	.745
Cog 1	.510	.754	.455
Cog 2	.595	.765	.615
Cog 3	.541	.837	.539

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An Analysis of Self-Reported Sleepiness and Fatigue Measures from Collegiate Aviation Pilots

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Sarah Wolfe
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Fatigue can be deleterious to pilot performance. The National Transportation Safety Board has called on the aviation community to reduce fatigue related accidents. Currently, there are few studies and guidance specific to collegiate aviation pilots. The current study is part of a larger effort by the authors to gain a clearer understanding of fatigue within the collegiate aviation environment. Collegiate aviation pilots are a unique group with different schedules, lifestyles, and demands when compared to airline, military, and on-demand pilots. The purpose of this study was to examine self-reported fatigue and sleepiness measures. Research instruments included the Karolinska Sleepiness Scale and the Samn-Perelli Fatigue Scale. The research team recruited thirty-two collegiate aviation pilots from a large Midwestern university. Participants were asked to record their sleepiness and fatigue ratings four times a day, at intervals, for a total of four weeks over four months. Approximately 5,000 total data points were collected. Results indicated a significant difference between the times of day. The 8:00 a.m. recording time had the highest median fatigue and sleepiness score. There were no significant differences between the days of the week. However, overall median fatigue and sleepiness scores indicated participants were slightly fatigued and sleepy throughout the data collection period.

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According to the National Transportation Safety Board (NTSB) (2018), fatigue is a "pervasive problem in transportation that degrades a person's ability to stay awake, alert, and attentive to the demands of safely controlling a vehicle, vessel, aircraft, or train" (p. 1). The International Civil Aviation Organization (ICAO) (2020) defines fatigue as:

> a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety-related duties. (p. 1)

Fatigue related accidents have become a concern for safety professionals. Consequently, reducing fatigue related accidents has been listed on the National Transportation Safety Board's top ten most wanted list since 2016 (NTSB, 2020). The NTSB is calling for a comprehensive approach to reducing the risks of fatigue in all sectors of transportation. Recommendations for combatting fatigue in the aviation sector include research, education, and training. The NTSB, the Federal Aviation Administration (FAA), aviation stakeholders, and the research community have worked extensively to address the issue, however, there seems to be a gap in these efforts. For instance, the FAA's existing policies and training are specific to maintenance technicians, scheduled services, and on-demand flight operations (FAA, 2010, 2012, 2014). Furthermore, the only FAA regulation for duty time during flight training is the Federal Aviation Regulation (FAR) 61.195. This regulation restricts flight instruction duties, which in the collegiate aviation environment often consists of upper-level college students. Specifically, the regulation restricts flight instruction hours to a maximum of eight per twenty-four hours (Electronic Code of Federal Regulations, 2020a).

Although this is a positive mitigation tool, the regulation does not consider all the tasks undertaken by the collegiate aviation pilots including instructions. Collegiate aviation pilots are a unique population. In addition to flying, these pilots face rigorous course loads, expectations to participate in student organizations, social activities, and often have part time jobs (Keller, Mendonca, & Cutter, 2019; Levin, Mendonca, Keller, & Teo, 2019; Mendonca, Keller, & Lu, 2019). According to Beattie, Laliberté, Michaud-Leclerc, and Oreopoulos (2019), students who thrive in the academic environment spend on average 30 hours a week studying. Many collegiate aviation pilots are in the 18-22 age range. Moreover, this is frequently their first time living away from home. Therefore, these individuals may be the least prepared group of pilots, as they are just beginning to develop their time management and coping skills while learning how to safely and effectively fly. Previous studies have indicated that a holistic approach to mitigate fatigue, which includes conducting research utilizing multiple methodologies, evidence-based training and education programs is vital (Mendonca et al., 2019; Signal, Ratieta, & Gander, 2006).

Purpose

The purpose of this study was to investigate the role of day of the week and time of the day on reported levels of sleepiness and fatigue by collegiate aviation pilots at a large Midwestern professional flight program. The research team utilized the 10-point Karolinska Sleepiness Scale (KSS) and the seven-point Samn-Parelli Fatigue Scale (SPS) to identify patterns in sleepiness and fatigue, respectively, throughout the day and longitudinally (ICAO, 2012). ICAO (2012) suggests using these scales to obtain a large data set efficiently. However, there are biases with self-reported measures. Findings of this study will contribute to the larger project which is intended to improve fatigue awareness, mitigation and management, training, and education for collegiate aviation pilots (Keller et al., 2019; Mendonca et al., 2019; Romero, Robertson, & Goetz, 2020). The following sections will discuss fatigue and the relationship to safety as well as previous research pertaining to self-reported sleep measures.

Literature Review

Time of Day, Fatigue, and Errors

An examination of the literature indicates fatigue awareness and mitigation are directed towards military and airline pilots (French & Garrick, 2005; Hamsal & Zein, 2019; Roach, Darwent, Sletten, & Dawson, 2011). There seems to be only a few studies that are specific to collegiate aviation pilots. The effects of sleep deprivation and physical fatigue are a continual focal point in transportation safety research. From 2016 to 2020, “Reduce Fatigue-Related Accidents” has been on the NTSB Most Wanted List as a primary safety focus (NTSB, 2018, p. 1). Many studies have been conducted with commercial airline and military flight crews (Gander et al., 2013; Powell, Spencer, Holland, Broadbent, & Petrie, 2007; Sieberichs & Kluge, 2016). Commercial flight crews are limited in duty time and flight time per day, while also subject to minimum rest requirements per 14 Code of Federal Regulations (CFR) Parts 117, 121, and 135 (Electronic Code of Federal Regulations, 2020b). Despite the importance for aviation safety, a prescriptive approach to mitigate fatigue in flight operations does not always consider other factors contributing to fatigue other that work duration (Signal et al., 2006). Even with regulatory rest protections, Mallis, Banks, and Dinges (2010) found only 50 to 75% of a normal rest period appears to account for sleep.

ICAO (2016) suggests that sleep loss may affect a pilot's ability to "anticipating events, planning and determining relevant courses of action - particularly under novel situations" (pp. 2-14). Pilots are required to plan and anticipate future actions and make split-second decisions, especially when critical life-threatening situations arise. According to Williamson and Feyrer (2000), 17 to 19 hours of wakefulness is equivalent to having a Blood Alcohol Content (BAC) of .10. The NTSB labels the hours of wakefulness as the *Time Since Awakening* (TSA) (NTSB, 1994). TSA measures the number of hours when the pilot first rises from bed to the time of the accident (NTSB, 1994). Flight crews with high TSA were recorded to have as much as 40% more mistakes overall as compared to low TSA counterparts (NTSB, 1994). NTSB data also indicate that errors of omission made by crews with high TSA rose by 75% (NTSB, 1994). Similarly, errors with monitoring automation rose by around 136% in pilots with high TSA flight crews (NTSB, 1994). As fatigue increases, errors made by an individual become more difficult to detect and correct (ICAO, 2016).

According to O'Hagan, Issartel, McGinley, and Warrington (2018), seven pilots participated in two 24-hour training sessions, one including an 8-hour rest period, and one without the rest period. The participants were prompted to complete tasks measuring cognitive flexibility, working memory, situational awareness, and hand-eye coordination every eight hours throughout each session. Results indicated the participant instrument scan and hand eye coordination suffered as well as pilot judgement due to fatigue. After 24 hours of continuous wakefulness the pilots reported significant levels of fatigue. Lopez, Previc, Fischer, Heitz, and Engle (2012) studied performance of Air Force pilots after 35 hours of sleep deprivation. Significant effects of fatigue began to show after 19 hours of wakefulness. Slight increases in performance were observed in the morning hours of the following day. This was possibly due to peaks in the circadian rhythm cycle, yet performance was still significantly lowered when compared to the beginning of the testing session. This finding may directly relate to collegiate student pilots who may not have the best sleep practices. The human body needs a consistent sleep cycle to be able to function at best performance. Students who have varying sleep schedules, late nights, and early mornings are highly subject to decreases in performance (Lopez et al., 2012).

The period in the day a flight occurs also has a significant effect on pilot performance due to circadian cycles. Early morning flights between the hours of midnight and 6:00 a.m. have shown decreases in performance regardless of the amount of rest received prior to duty. Mello et al. (2008) analyzed Brazilian airline pilot errors in relationship to the time of day. The data showed 9.5 errors per 100 flight hours during the early morning hours while later times of day averaged 6.7 errors per 100 flight hours. Previc et al. (2009) also noted the effect of circadian cycle in performance of pilots. Fatigue significantly increased and performance decreased at midnight. A slight decrease in fatigue and sleepiness did not occur until after 9:30 a.m.

These articles provided evidence that relationships exist between time of day, fatigue levels, and errors. Additionally, the methodologies provide an adequate framework for collegiate aviation pilots. Though there have not been many studies specific to collegiate aviation pilots, there has been a recent emerging effort by scholars.

Fatigue within the Collegiate Aviation Flight Environment

Mendonca, Keller, and Lu (2019) validated and distributed the Collegiate Aviation Fatigue Inventory (CAFI) to a Midwestern collegiate aviation flight program. One hundred and twenty-two pilots responded to the survey. Results indicated that 92% reported to have never fallen asleep or struggled to stay awake during a flight. However, 51% indicated they proceeded with a flight despite being extremely tired. Additionally, respondents reported cognitive dysfunction during flight activities. Moreover, their responses suggested that lack of sleep was a primary cause to their fatigue. In another study, researchers surveyed collegiate aviation pilots. Results indicated flying after a long day, flying after less than eight hours of rest, and insufficient quality of sleep were the top three causes of fatigue (Romero et al., 2020).

Keller et al. (2019) utilized fatigue-related scenarios to understand pilot decision-making. Results indicated participants did not always express desirable decision-making processes. Additionally, findings indicated participants had insufficient knowledge about the effects of fatigue as well as effective mitigation strategies. Pilots reported external factors such as organizational pressures as a key aspect towards undesirable decisions. Levin, Mendonca, Keller, and Teo (2019) reported that 86% (*n* = 141) of the surveyed participants believed that fatigue had a negative impact on the safety of a flight operation. Additionally, approximately 85% of respondents indicated they had not been formally trained on fatigue topics. It is important to mention that Keller et al., (2019), Mendonca, Levin, Keller and Teo (2019), and Romero et al. (2020) have clearly argued that further fatigue research within a collegiate aviation environment is fundamental for aviation safety and efficiency. The previous studies pertaining to fatigue within the collegiate aviation environment did not use self-reported measures. Therefore, examining fatigue with a different methodology will add to the body of knowledge.

Measuring Fatigue Through Self-Reporting Measures

According to ICAO (2016), there are five methods for proactive fatigue identification. These five are self-reporting measures, surveys, performance data, research studies, and the analysis of time worked. Benefits to utilizing rating scales such as the Karolinska Sleepiness Scale (KSS) and Samn-Parelli Scale (SPS) include the simplicity, cost-effectiveness, and ability to collect a large amount of data (ICAO, 2012). However, self-reported scales are subject to biases. These biases may come in two primary ways. First, a respondent may not want to tell the truth about their fatigue state. Secondly, a person may not always be able to accurately detect the true level of fatigue because of its insidious nature and or the individual's emotional status (Garwon, 2016). There has yet to be a study in the collegiate aviation environment utilizing self-reported measures. However, robust studies using both the KSS and the SPS have been published from the airline environment (Gander et al., 2013; Gawron, 2016; Powel et al., 2007; Van den Berg et al., 2015).

Van den Berg et al. (2015) measured flight crew members fatigue and sleepiness to evaluate the effectiveness of fatigue management strategies during ultra and non-ultra-long-range flights. Participants were asked to provide their responses before and after a sleep break during the flight. Additionally, the participants were asked to rate their workload and complete a five-minute Psychomotor Vigilance Test (PVT). Results indicated the fatigue and sleepiness ratings were higher on the non-ultra-long-range flights. This provided evidence that longer flights do not always constitute more fatigue. This was attributed to better management of sleep recovery periods between ultra-long-range flights. It was recommended that airlines should further investigate workload patterns for shorter flights. In another study, the KSS and SPS were used to evaluate pilots operating long-range and ultra-long-range flights. It was found that total sleep time was a significant predictor for both the KSS an SPS ratings (Cosgrave, Wu, van den Berg, Signal, & Gander, 2018). Levo (2016) utilized the KSS to measure pilot sleepiness over the course of five flights. Results indicated a higher fatigue rating after the fourth flight during the week that was recorded. This study contributed to understanding workload management and fatigue risk management efforts. Previous studies (Gander et al., 2013; Honn, Satterfield, Mccauley, Caldwell, & Van-Dongen, 2016; Shahid, Shen, & Shapiro, 2010) have demonstrated that both the KSS and SPS are valid tools to assess subjective measures of sleepiness and fatigue, respectively.

Pilot fatigue is a serious detriment to aviation safety. As pilots become more fatigued performance decreases while accepted standards of performance and safety decreases (Caldwell, 2012). The review of literature indicated there are few fatigue studies pertaining to collegiate aviation pilots and there may be a gap in fatigue training and education; however, there is an emerging effort in that direction (Keller et al., 2019; Levin et al., 2019; Mendonca & Keller, 2020; Romero et al., 2020). Once again, this study is part of a larger effort to gain a clearer understanding of fatigue specific to the collegiate aviation pilots. Previous phases of the research project utilized surveys and fatigue-related decision-making scenarios (Keller et al., 2019; Levin et al., 2019; Levin & Teo, 2019; Mendonca, Keller, Lu, 2019). When combining the results of the different studies, the collegiate aviation community may have a clearer understanding of the issue and could then develop more efficient holistic strategies to mitigate fatigue during flight training activities. In order to understand fatigue and sleepiness among collegiate aviation pilots, the following research questions were addressed:

1. Is there a significant difference between the time of day (8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m.) and the median KSS scores?
2. Is there a significant difference between the time of day (8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m.) and the median SPS scores?
3. Is there a significant difference between days of the week and the median KSS scores?
4. Is there a significant difference between days of the week and the median SPS scores?

Methodology

Sample

The participants in this study were undergraduate students enrolled in a Midwest Part 141 four-year collegiate aviation flight program. All participation was in accordance to Institution Review Board (IRB) guidelines. Researchers sought collegiate aviation pilots, aged 18 years or older, who had previously flown in the last six months, and were currently enrolled in a Part 141 flight training program.

Recruitment and Procedures

After obtaining IRB approval, the research team sent an email asking for participation. Two information sessions were conducted to accommodate student schedules. During the information sessions, the prospective participants were informed about the research project, their rights as participants, the procedures, and then given consent forms to sign. The participants who agreed to continue were re-informed of the procedures, asked to provide demographic information, and to sign the consent form. A presentation was given to describe the scales and their purpose.

The researchers asked students to document their fatigue and sleepiness levels at 8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m. each day, using the SPS and KSS, respectively. The data collection process occurred during four weeks spread in four consecutive months.

The weeks out of the four months were randomly selected through an online random number generator. Two reporting weeks were at the end of the Fall 2019 semester and the remaining two weeks were at the Spring 2020 semester. The research team desired to have a broad perspective of fatigue and sleepiness levels longitudinally. Each day at the four sampled times, a reminder was sent to the participants for them to record their sleepiness and fatigue scores. Participants received $20 each week for a total of $80.

Research Instruments

The research team utilized the 10-point Karolinska Sleepiness Scale (KSS) and the seven-point Samn-Perelli Scale (SPS) (ICAO, 2012) to identify patterns in fatigue and sleepiness throughout the day and longitudinally during alternate weeks throughout the period of four months. ICAO (2012) suggests using these scales to obtain a large dataset efficiently. According to Gander et al., (2013), both scales, recommended by ICAO (2012), have been used in the airline industry. The KSS and SPS are very similar in nature; however, they are used to assess different constructs, subjective sleepiness, and subjective fatigue levels. Sleepiness often pertains to the physiological act of falling asleep while fatigue may be more physical. For example, an individual may have obtained nine hours of sleep but had to take a challenging check ride which required extreme concentration. They may not be sleepy after the check ride but mentally fatigued. The research team decided to use both scales because it would not significantly increase participant time to report while providing an abundance of data. It was estimated it would take participants a few seconds to record their responses. Table 1 shows the KSS and SPS scales.

Table 1.
Karolinska and Samn-Perelli scales

Karolinska Sleepiness Scale (KSS) 10-point scale	Samn-Perelli Fatigue Scale (SPS) 7-point scale
1=Extremely alert	1=Fully alert, wide awake
2=Very alert	2=Very lively, responsive, but not at peak
3=Alert	3=Okay, somewhat fresh
4=Rather alert	4=A little tired, less than fresh
5=Neither alert nor sleepy	5=Moderately tired let down
6=Some signs of sleepiness	6=Extremely tired, very difficult to concentrate
7=Sleepy, but no effort to keep awake	7=Completely exhausted, unable to function effectively
8=Sleepy, but some effort to keep awake	
9=Very sleepy, great effort to keep awake, fighting sleep	
10=Extremely sleepy, can’t keep awake	

Note. International Civil Aviation Organization. (2012). *Measuring fatigue*. Retrieved from https://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/Doc%209966.FRMS.2011%20Edition.en.pdf

Data Analysis

The data collection period was during the Fall 2019 and Spring 2020 semesters. The researchers combined the data within a spreadsheet by scale, time of day, and week. Then the data was transferred over to SPSS®. Demographics, descriptive statistics, and four Kruskal-Wallis H tests are reported in the results section. The Kruskal-Wallis H test is a non-parametric test that can determine if there are significant differences between groups of independent variables (time of day and days of the week) on a ordinal dependent variable (self-reported fatigue and sleepiness measures) (Laerd Statistics, 2020).

Results

Demographics

Thirty-two participants (*n* = 32) agreed to participate in the study. Ninety-one percent were male while nine percent were female. Eighty-one percent of the participants were between the ages 18-20, 13% were between the ages 21-25, and six percent were between ages 26-35. Twenty-eight percent were freshmen, 34% were sophomores, 22% were juniors, 13% were seniors, while three percent were combined degree program students. The combined degree program allows undergraduates to enroll into graduate courses. Twenty-five percent of the participants held student certificates, 47% held private pilot certificates, 28% held commercial certificates. Twenty-five percent had less than 100 hours of total flight hours, 43% reported between 101-200 total flight hours, 25% percent reported 201-400 hours of total flight time, and seven percent reported between 401-1,000 total flight hours. These demographics are shown in Table 2.

Table 2.
Summary of participant demographics

Gender		
Male	29	91%
Female	3	9%
Total	32	100%
Enrollment Status		
Freshman	9	28%
Sophomore	11	34%
Junior	7	22%
Senior	4	13%
Combined Degree	1	3%
Total	32	100%
Highest Certificate Held		
Student	8	25%
Private	15	47%
Commercial	9	28%
Total	32	100%
Flight Hours		
<100	8	25%
101-200	14	43%
201-400	8	25%
401-1000	2	7%
Total	32	100%

Note. The percentages were rounded to the nearest whole number.

Research Question One

Is there a significant difference between the time of day (8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m.) and the median KSS scores?

In order to answer the first research question, the first analysis conducted was for the KSS measures. After four weeks of data collection, 2,789 total data points were obtained. Figure 1 shows the box plot for distribution of the reported KSS scores.

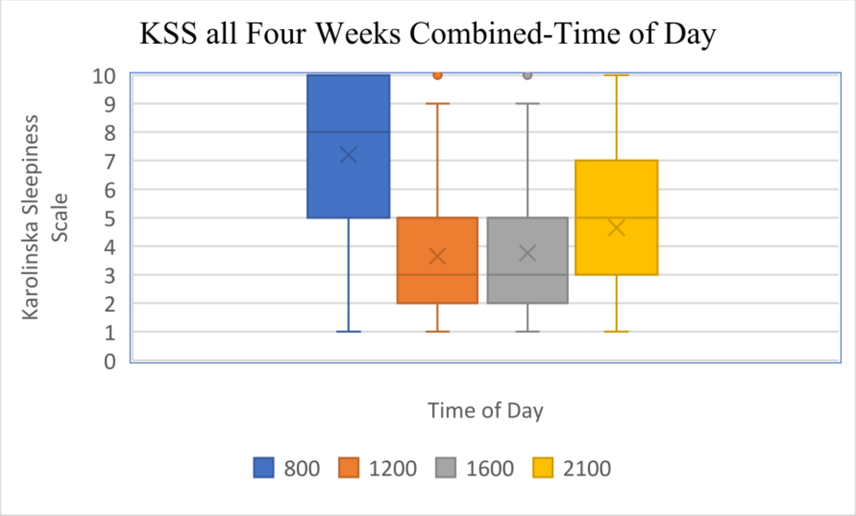

Figure 1. KSS box plot for all four weeks combined and time of day.

A Kruskal-Wallis H-test was run to determine if there were significant differences between the KSS scores during the four time periods of the day: Morning 8:00 a.m. (*n* = 707), Noon 12:00 p.m. (*n* = 704), Afternoon 4:00 a.m. (*n* = 698), and Night (9:00 p.m. (*n* = 680). Distributions of median KSS scores were similar for all identified time periods of the day, as assessed by visual inspection of the boxplot. Median KSS scores decreased from Morning 8:00 a.m. (*M*= 8-Sleepy, but some effort to keep awake), to Noon 12:00 p.m. (*M* = 3-Alert), remained the same for the Afternoon 4:00 a.m. (*M* = 3 Alert), then slightly increased for the Night 9:00 p.m. period (*M* = 5-Neither alert nor sleepy). The median KSS scores were statistically significantly different between time of day, $\chi2(3) = 600.532$, $p < .001$.

Subsequently, pairwise comparisons were performed using Dunn's (1964) procedure. A Bonferroni correction for multiple comparisons was made with statistical significance accepted at the $p < .0083$ level. This post hoc analysis revealed statistically significant differences in KSS scores between all the times periods of day except for the Noon 12:00 a.m. and Afternoon 4:00 p.m. time periods. Table 3 shows the pairwise comparisons for the time of day and KSS scores.

Table 3.
Pairwise comparisons of time of day and KSS scores

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
12:00 p.m.-4:00 p.m.	-42.167	42.723	-.987	.324	1.000
12:00 p.m.9:00 p.m.	-312.774	43.006	-7.273	.000	.000
12:00 p.m.-08:00 a.m.	924.303	42.586	21.704	.000	.000
4:00 p.m.-9:00 p.m.	-270.607	43.097	-6.279	.000	.000
4:00 p.m.-08:00 a.m.	882.136	42.678	20.670	.000	.000
9:00 p.m.-08:00 a.m.	611.529	42.961	14.234	.000	.000

Note. Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests (.0083).

Research Question Two

Is there a significant difference between the time of day (8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m.) and the median SPS scores?

In order to answer research question two, the second analysis was conducted for the SPS measures. After four weeks of data collection, 2,738 total data points were obtained for all four time periods 8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m. Figure 2 shows the box plot for distribution of the reported SPS scores.

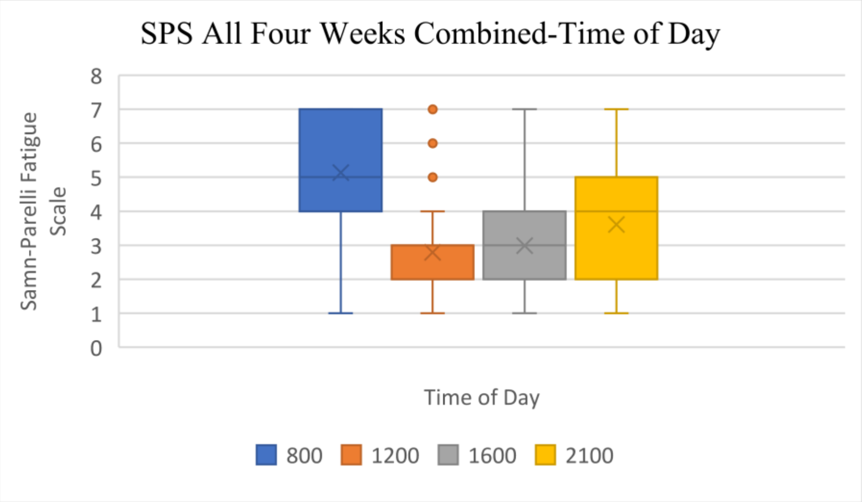

Figure 2. SPS box plot for all four weeks combined and time of day.

A Kruskal-Wallis H test was run to determine if there were differences in SPS scores between the four time periods of the day: Morning 08:00 a.m. (*n* = 700), Noon 12:00 p.m. (*n* = 682), Afternoon 4:00 (*n* = 677), and Night 9:00 (*n* = 679). Distributions of median SPS scores were similar for all the identified time periods, as assessed by visual inspection of the boxplot. Median SPS scores decreased from Morning 08:00 a.m. (*M* = 5-Moderatley tired, let down), to Noon 12:00 p.m. (*M* = 3-Okay, somewhat fresh), remained the same for the Afternoon 4:00 p.m. (*M* =3-Okay, somewhat fresh), then slightly increased for the Night 9:00 p.m. period (*M* = 4-A little tired, less than fresh). SPS scores were statistically significantly different between time of day, $\chi2(3) = 600.205$, $p < .001$.

Subsequently, pairwise comparisons were performed using Dunn's (1964) procedure. A Bonferroni correction for multiple comparisons was made with statistical significance accepted at the $p < .0083$ level. This post hoc analysis revealed statistically significant differences in SPS scores between all the times periods of day except for the Noon 12:00 p.m. and Afternoon 4:00 p.m. time periods. Table 4 shows the pairwise comparisons for the time of day and SPS scores. Both scales provided similar evidence to fatigue levels at the recorded times.

Table 4.
Pairwise comparisons of time of day and SPS scores

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
12:00 p.m.-4:00 p.m.	-106.178	42.309	-2.510	.012	.073
12:00 p.m.-9::00 p.m.	-394.690	42.278	-9.336	.000	.000
12:00 p.m.-08:00 p.m.	935.998	41.959	22.307	.000	.000
4:00 p.m.-9:00 p.m.	-288.512	42.356	-6.812	.000	.000
4:00 p.m-08:00 a.m.	829.820	42.038	19.740	.000	.000
9:00 p.m.-08:00 a.m.	541.308	42.006	12.886	.000	.000

Note. Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests (.0083)

Research Question Three

Is there a significant difference between days of the week and the median KSS scores?

Regarding the KSS by days of the week, there were 2,797 data points collected. Figure 3 shows the box plot for distribution of the reported KSS scores.

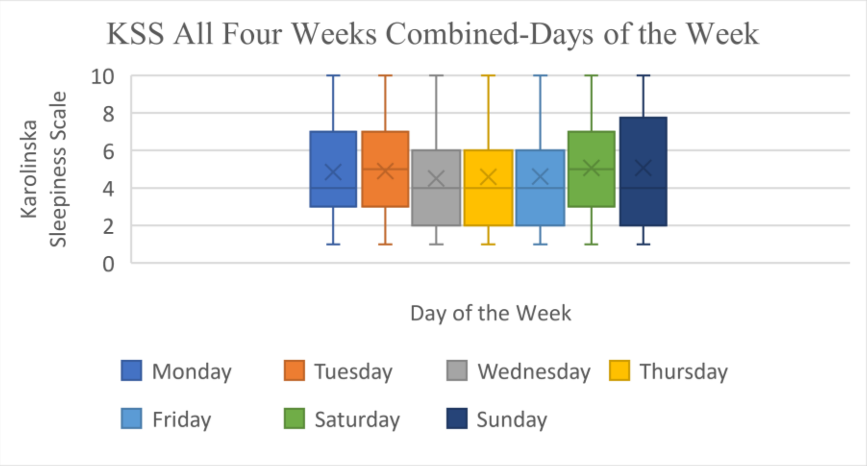

Figure 3. KSS box plot with all four weeks combined and days of the week.

Another Kruskal-Wallis H test was run to determine if there were differences between KSS scores and each day of the week: Monday (*n* = 432), Tuesday (*n*= 412), Wednesday (*n* = 407), Thursday (*n* = 407), Friday (*n* = 390). Saturday (*n* = 377), and Sunday (*n* = 372). Distributions of median KSS scores were similar for all seven days of the week, as assessed by visual inspection of the boxplot. Median KSS scores were also similar for each day. Monday (*M* = 4- A Rather Alert), Tuesday (*M* = 5-Neither alert nor sleepy), Wednesday (*M* = 4- A Rather Alert), Thursday (4- Rather Alert), Friday (4- Rather Alert), Saturday (*M* = 5- Neither alert nor sleepy), and Sunday (*M* = 4- Rather Alert). Median SPS scores were not statistically significantly different between the days of the week, $\chi 2(3) = 12.422$, $p = .053$.

Research Question Four

Is there a significant difference between days of the week and the median SPS scores?

The fourth and final statistical test is for the SPS scores and days of the week. After four weeks of data collection, 2,817 total data points were obtained for all seven days of the week. Figure 4 shows the box plot for distribution of the reported SPS scores.

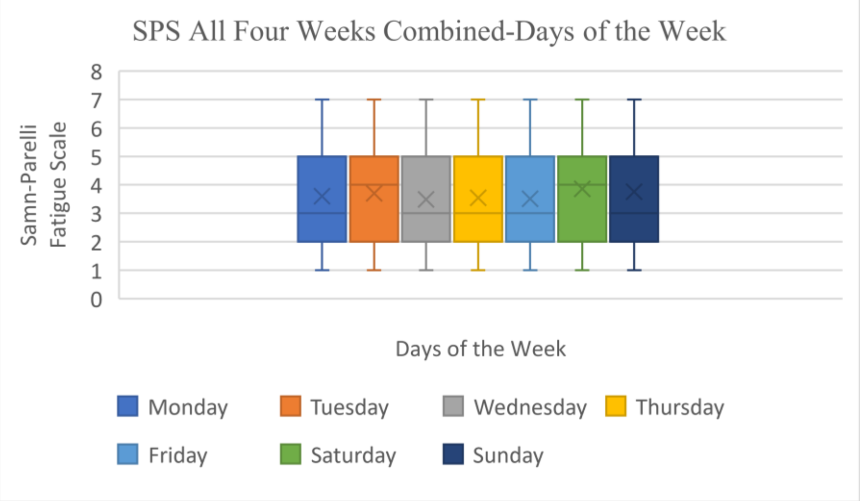

Figure 4. SPS boxplot with all four weeks combined and days of the week.

The final Kruskal-Wallis H test was run to determine if there were differences in SPS scores between each day of the week: Monday (*n* = 438), Tuesday (*n*= 412), Wednesday (*n* = 403), Thursday (*n* = 409), Friday (*n* = 402). Saturday (*n* = 386), and Sunday (*n* = 367). Distributions of median SPS scores were similar for all days of the week, as assessed by visual inspection of the boxplot. Median SPS scores were also similar for each day. Monday (*M* = 3-Okay, somewhat fresh), Tuesday (*M* = 4-A little tired, less than fresh), Wednesday (*M* = 3-Okay, somewhat fresh), Thursday (*M* = 3-Okay, somewhat fresh), Friday (*M* = 3-Okay, somewhat fresh), Saturday (*M* = 4-A little tired, less than fresh), and Sunday (*M* = 3-Okay, somewhat fresh). Median SPS scores were not statistically significantly different between the days of the week, $\chi 2(3) = 9.900$, $p = .129$. Both scales provided similar evidence.

Discussion and Conclusion

This study is part of larger research effort and sought to understand fatigue and sleepiness among collegiate aviation pilots at a large Midwestern university. The collegiate aviation flight training environment is the primary source for producing professional pilots in the industry. Therefore, they must be trained appropriately and prepared for their current training environment and future challenges as professional pilots in the industry. Collegiate aviation is safe. This is proven by the thousands of successful flight training operations that occur each year. However, pilot fatigue is a serious detriment to aviation safety and can inhibit learning as well as student progress. A proactive approach through data collection is necessary to mitigate threats to safe flight operations (ICAO, 2012). This study provided robust information for not only collegiate aviation pilots but also flight training managers. The Kruskal-Wallis H test provided evidence the sample population was mostly fatigued and sleepy during the 08:00 a.m. recording time. This result is in alignment with previous research. According to Mello et al. (2008), the most errors by pilots were committed in the morning hours when fatigue levels were high. Interestingly, a previous study by Mendonca et al. (2019) suggested that collegiate aviation pilots are more fatigued during the early hours of the day (6:00am to 9:00am).

There were no significant differences found between the days of the week for both the KSS and SPS scales. Interestingly, the participants median SPS score for each day of the week ranged from *3-Okay, somewhat fresh* to *4-A little tired, less than fresh* while the KSS median score ranged from *4-Rather alert* to *5-Neither alert nor sleepy*. This may indicate the participants were slightly sleepy and fatigued while making it through each day. Desirably, students should feel alert, fresh, and lively throughout the day. It is not new knowledge that best method to prevent fatigue is getting enough rest (Caldwell, 2012; ICAO, 2016). According to Romero et al., (2020), collegiate aviation pilots have struggled to get adequate sleep in both quantity and quality. This may be due to inadequate sleep preparation including preparing a proper sleeping environment i.e. temperature, putting away electronic devices, noisy dorm rooms, and planning for 7-9 hours of sleep. Additionally, Mendonca, Keller, and Lu (2019) found that students battle with having healthy lifestyles. Therefore, future research can further examine the barriers to effective sleep and lifestyle habits. This can be accomplished through focus groups and interviews. Though it is impossible to control student behavior outside of the classroom, it is possible that proper research-based training and education can promote desirable behaviors.

The authors acknowledge this study had several limitations. It was conducted at one collegiate aviation program and resources were limited. Additionally, there is potential bias in self-reporting data such as reluctance to be truthful and reporting the true nature of the fatigue level. Moreover, the researchers utilized a convenience sampling method, which unfortunately, did not include flight instructors. Caution should be given towards generalizing the results of this study to all collegiate aviation pilots. Furthermore, the researchers did not ask participants to report what they were doing prior to and the moment of reporting or the quality of their sleep. Nonetheless, results can still provide the foundation for safety efforts and research strategies to mitigate fatigue during flight training.

Practical applications may be derived from this study. Management and faculty can require formal fatigue mitigation and management training to all flight students. Program leaders can continue to develop and implement fatigue risk management systems, as suggested by ICAO (2012). In addition, the use of self-reported measures in conjunction with student workload management should be encouraged. Lastly, it is recommended that a robust assessment of fatigue be conducted prior to adding early morning and or later flight slots for the purpose of increasing capacity. Specific attention should be given to existing early morning and late flight slots as well as student-to-instructor ratio.

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