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Fatigue in Aircraft Maintenance Technician Schools

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Fatigue is a complex phenomenon that is different, if ever so slightly, from sleepiness (Shen et al., 2006). It is most commonly thought of as a continuous feeling of sleepiness and tiredness, and has been formally defined by Phillips (2015) as 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)

From the fatigue definition provided by Phillips (2015), four main elements or characterizing features can be highlighted. First of all, fatigue is a so-called suboptimal condition, indicating that when fatigued one's physical and mental capacity will not correspond to the optimal, best possible level of performance. Second, fatigue is a consequence of exertion, in other words, some form of activity or effort. Third, the level or degree of exertion, and thus, fatigue, is highly and inherently individualistic, with dependence on an individual's habits, lifestyle, as well as environmental factors. Last but not least, this level of (over-)exertion may influence daily activities. This last component of Phillip's (2015) fatigue definition is further highlighted by the Federal Aviation Administration (FAA). Specifically, the FAA (2012) describes that a lack of alertness coupled with a decline in both, physical and mental performance are common traits in fatigued individuals.

In aviation, fatigue susceptibility has been found to be a factor of the duration of shifts, the scheduling of shifts, as well as the amount of sleep prior to a shift (Bendak & Rashid, 2020; Rankin, 2011). Aviation maintenance technicians (AMTs) are a group known to be susceptible to these risks given the inherent characteristics of their profession. These include long shifts, night shifts, and irregular shifts, all three of which can result in a disrupted sleep schedule and cycle (Avers & Johnson, 2011; Hobbs et al., 2011). In an international survey conducted by Santos and Melicios (2019), aviation maintenance technicians reported work weeks of up to 100 hours. Moreover, aviation maintenance personnel are known for their lack of sleep, having a sleep debt of twice the national average (Avers & Johnson, 2011; Avers, 2015). Thus, especially fatigue related to sleep (or rather, a lack of sleep and rest) in aviation maintenance personnel has been known and observed to have detrimental effects on performance, but also safety (Avers, 2015; Wang & Chuang, 2014). For instance, as outlined by Avers (2015), personnel working 12-hour shifts, which is not uncommon for AMTs, have been found to be

more likely to be involved in mishaps that involve injuries than personnel working eight-hour shifts.

Given the compromised alertness together with the decrease in mental and physical capabilities described by the FAA (2012) and Phillips (2015), fatigue can become a serious and considerable hazard and lead to an increase in on-the-job errors (Drury, 2015; Kleidon, 2010; Santos & Melicios, 2019; Williamson et al., 2011). In a study performed by Marcus and Rosekind (2017), fatigue was found to be a factor of interest or concern, and considered in 20% of the investigations performed by the National Transportation Safety Board (NTSB) between 2001 and 2012. Similarly, the Aviation Safety Reporting System (ASRS) has a record of 21% of incidents being fatigue-related (Wang & Chuang, 2014). In addition, as reported by Santos and Melicios (2019), a large majority of maintenance personnel has indicated being aware of someone making mistakes influenced by fatigue. Furthermore, as shown in a survey conducted by Hackworth et al. (2007), there appears to be a general understanding among AMTs of the risks associated with being fatigued on the job and the safety hazards associated therewith.

Consequently, fatigue should be critically considered in aviation operations and related activities (Caldwell, 2005). As will be further outlined in subsequent paragraphs, a comparatively large volume of research has been performed with the goal of addressing fatigue in flight crews, while regulatory actions have been taken to limit their flight time and require rest periods (Title 14 Code of Federal Regulations [C.F.R.] § 91.1059, 2003; Title 14 C.F.R. § 121 Subpart R, 2012; Title 14 C.F.R. § 121.467, 2018; Title 14 C.F.R. § 135.267, 1996). For maintenance technicians, at least in the United States, regulations requiring rest periods or addressing fatigue-related topics that could be taken as an initial step to minimize fatigue in this field are scarce. Under 14 C.F.R. Part 121 duty limitation times are regulated for maintenance technicians, mandating a minimum 24-hour rest period per week (Title 14 C.F.R. § 121.377, 1964). However, researchers determined that these rest periods do not offer a solution to the problem per se (Rankin, 2011). As such, further action in this field should (rather, needs to) be taken to avoid future accidents and injuries stemming from fatigue in maintenance personnel (Eisenbeil, 2015; Hackworth et al., 2007; Santos & Melicios, 2019).

In order to address fatigue in the flight deck, the FAA has provided a series of guidance material in addition to the essential regulatory requirements detailed above. In these references, the importance of sleep is reinforced, outlining that adequate rest can be a successful factor in avoiding or minimizing fatigue (FAA, 2012/2020). Mendonca et al. (2019) reinforced that preventing fatigue in the first place is the key to avoiding fatigue-related incidents and accidents. Caldwell (2005), however, further outlines that sleep and rest can be effective at addressing fatigue, but are not the only methods to tackle these issues. Consequently, Avers and Johnson (2011), Banks et al. (2013), Caldwell (2005), Caldwell, Mallis, et al.

(2009), Caldwell, Chandler, et al. (2012), as well as Rankin (2011) highlight the criticality of approaches such as education and training, cooperation between all stakeholders, improving scheduling, acknowledging individual differences as well as following scientifically developed methods to reduce fatigue-related issues while on the job. Moreover, one of the systematic approaches that can be used or implemented in the field of aviation maintenance to mitigate the negative impact on operations are the so-called fatigue risk management (FRM) programs (Avers & Johnson, 2011; Avers, 2015; Hobbs et al., 2011; Rankin, 2011).

The body of research introduced above focuses specifically on professional aircraft maintenance technicians. However, similar fatigue themes can be transferred to a collegiate environment, in AMT training. While the collegiate environment may present lesser challenges from a time pressure and performance perspective, other stressors and factors influencing fatigue are present in the educational process.

Literature Review

This train of thought has been primarily applied to flight training and collegiate flight programs, where researchers have noted that the collegiate environment is different from the professional aviation industry, and as such, presents unique research-worthy challenges (Mendonca, Keller, Levin, et al., 2019). Levin et al. (2019), Romero et al. (2020), as well as Teo (2020) identified a lack of quality sleep, irregular sleeping schedules, coupled with workload management, stress, and an unhealthy lifestyle to be among the top fatigue, inducing factors in a collegiate flight school setting. However, as outlined by Mendonca, Keller, and Lu (2019), other elements of collegiate life, including, but not limited to, early schedules, long workdays, as well as social factors can have detrimental consequences on students' fatigue levels. Keller et al. (2020) and Mendonca et al. (2021) further narrowed down the topic to investigate more nuisance elements that comprise students' fatigue levels, such as time of the day, day of the week, detailed schedules, fatigue training, and flight fitness and preparedness. Furthermore, it is crucial to acknowledge differences in fatigue training and behavior among the different age groups in the collegiate environment. As found by Keller et al. (2021) and Teo (2020), upper-classmen, especially juniors and seniors, are more likely to misjudge their fatigue and continue flying as usual while simultaneously having received less fatigue training. These studies, similarly, are being expanded to not solely rely on surveys to collect data. For instance, Keller et al. (2019) recorded collegiate pilots' responses to decision-making scenarios (instead of a survey) to better understand the students' thought processes related to fatigue-influenced decisions and situations.

While the studies introduced above have a specific focus on flight programs, the items evaluated are not inherently unique to flight students. As such, students in aviation maintenance-centered programs may be subjected to and experiencing

similar conditions throughout their academic lives. Specifically, aviation maintenance students are similar to flight students exposed to a collegiate environment, and thus might encounter similar pressures (i.e., work-load management, stress, and balancing classes to list some examples) that could impact their fatigue levels. Moreover, aviation maintenance students also have a hands-on component to their education, primarily consisting of time in laboratories practicing different maintenance-related activities. While the regulations do not call out a specific number of hours students need to spend in laboratories versus lectures, a significant amount of time of classroom participation, specifically, 1,900 hours for airframe and powerplant combined or 1,150 hours for each rating separately, has been required for maintenance students until this year (Aviation Maintenance Technician Schools, 2022; Title 14 C.F.R. Part 147, 1962). Consequently, there is also a safety hazard stemming from aviation maintenance students being fatigued. Even if different from the inherent risk of flying while fatigued that flight students face, being in a laboratory environment with hazardous equipment is against safe work practices. By extension, as presented in the literature above, in the work field, in addition to being around hazardous equipment, fatigue in maintenance technicians can lead to mistakes and errors. These, in turn, can detrimentally impact flight safety.

Thus, the conducted study aims to investigate fatigue in aviation maintenance students. Specifically, the goal of this study is to evaluate how, and which, fatigue-related factors and attitudes, as identified in the literature review above, influence Part 147 (i.e., A&P) university students. By understanding said factors and attitudes, a better understanding of the fatigue-related risks that students face can be obtained, while simultaneously serving as the basis to develop training or other countermeasures.

Survey

With the goal of understanding the fatigue attitudes and perceptions, together with the general thoughts thereof and the lifestyle and habits that may influence the fatigue of students, a survey was conducted at an undergraduate aviation program in the United States. Specifically, students of 100-, 200-, 300-, and 400-level classes (corresponding to freshman, sophomore, junior, and senior level classes, respectively) were asked to voluntarily participate in the survey. The survey was distributed and completed electronically during the class periods towards the end of the Spring 2022 academic semester. By allowing students across the four undergraduate levels to participate, an adequate representation of the student body was aimed to be obtained.

The survey was divided into two main sections: (1) demographic questions and (2) fatigue-related questions. The former includes seven questions aimed to obtain an understanding of the demographic features and attributes of the participants. The latter includes 12 statements to be rated along the *never-always*

spectrum, 14 ranking statements along the *strongly disagree-strongly agree* spectrum, as well as one multiple choice and free response question, each. The survey questions and statements were based on previous aviation and collegiate fatigue-related research and published works by Levin et al. (2019) as well as by Mendonca, Keller, and Lu (2019). The full survey can be found in the Appendix.

The four classes surveyed are part of a four-year university undergraduate curriculum centered around, and focusing on, aviation maintenance. In addition, the same program allows students to opt into a so-called Airframe and Powerplant (A&P) minor, which prepares students to test for the FAA Airframe and Powerplant certificate, commonly referred to as the A&P. As such, the program is bound by federal regulations under Title 14 C.F.R. Part 147 (1962), hereby abbreviated as Part 147, that control aviation maintenance technician schools (AMTS). Therefore, the regulations, and especially, the requirements, set forth under Part 147 (Title 14 C.F.R. Part 147, 1962) need to be considered when evaluating the survey results.

Results

A total of 72 complete answers were recorded and included in the analysis. More answers were originally received, however, only entries with a 100% response rate were considered. Key features of the participants' demographic information in terms of age and class standing distributions are shown in Tables 1 and 2 below. In addition to the details shown in Tables 1 and 2, it is noteworthy to highlight that the participant sample was primarily male (specifically, 55 participants identified as male) and included students not only from the maintenance-focused program, but also from other aviation-related educational programs. By extension, eight participants indicated that they are completing two or three collegiate degrees simultaneously - a feat commonly associated with higher workloads.

Table 1
Age Distribution of Participants

Age (Years)	Count	Percentage
18	6	8.3333%
19	18	25.0000%
20	16	22.2222%
21	10	13.8889%
22	11	15.2778%
23	5	6.9444%
24	2	2.7778%
25	2	2.7778%
34	1	1.3889%
38	1	1.3889%

Table 2
Class Distribution of Participants

Class Standing	Count	Percentage
Freshman	17	23.6111%
Sophomore	24	33.3333%
Junior	9	12.5%
Senior	22	30.5556%

In terms of potentially pursuing a career in aircraft maintenance, 66 of the 72 participants (slightly over 90%) indicated that they are also part of the A&P minor. Moreover, 65 participants indicated an intent to actually pursue the A&P certificate after graduation. As mentioned above, the minor is not a requirement, but instead a voluntary option which provides students with the education needed to take the exam to obtain the A&P certificate. Similar to pursuing multiple degrees simultaneously, completing the A&P minor correlates to taking additional classes, which also present more stringent attendance requirements and supplemental time

in laboratories. Table 3 below outlines the distribution of the time participants have spent in the A&P (i.e., Part 147) program.

Table 3
Distribution of Years in the A&P Program

Time in A&P Program	Count	Percentage
Less than 1 Year	3	4.5455%
From 1 to 2 Years	20	30.3030%
From 2 to 3 Years	21	31.8182%
From 3 to 4 Years	11	16.6667%
4 or More Years	11	16.6667%

From the demographic information presented above, it is possible to identify a comparatively even distribution of ages (especially in the 19 to 22 years age group), class standing (with some underrepresentation of juniors), and time spent in the A&P program. For the latter, nevertheless, a greater representation of participants having spent between one to three years in the A&P program and three years and over is observed. This can be explained by students transferring into the A&P program at a later point in their collegiate career and completing the Part 147 requirements in a smaller time frame.

Referring to the fatigue-oriented responses, Table 4 below presents the distribution of the self-reported sleep amount of the participants, while the results from the ranking questions are presented in Figures 1 through 5. Moreover, Table 5 provides a summary of the recurring themes obtained from the 21 entries to the (optional) free response question. In this prompt, participants were asked to identify any further factors that impact their fatigue levels, other than the ones previously identified in the ranking questions (see Figures 1 through 5). Some themes were repeated, and some entries included more than one theme. Thus, the sum of the counts of Table 5 is greater than the number of entries (i.e., 21).

Table 4
Distribution of Participants' Self-reported Sleep

Sleep Quantity	Count	Percentage
0 to 2 Hours	4	5.5556%
2 to 4 Hours	5	6.9444%
4 to 6 Hours	19	26.3889%
6 to 8 Hours	37	51.3889%
8 to 10 Hours	7	9.7772%

Table 5
Additional Factors Impacting Participants' Fatigue Levels

Theme	Count	Details and Specifics
Family/ Relationships	5	Kids, partners, pets, and family
Homework	5	Quantity, for non-major classes, assigned over the weekend, interferes with work schedule
Work	2	-
Military duties	2	-
Nutrition	2	-
Long school days	2	Early/late classes, no breaks
Jobs	2	Reduced time over weekends to do homework/study
Other themes	Once each	Weather, extracurriculars, physical demands (long sitting/standing), class difficulty, mental health, and being away from home

Figure 1

Answer Distributions to “Please select the accuracy of the statements below referring to your current lifestyle:”

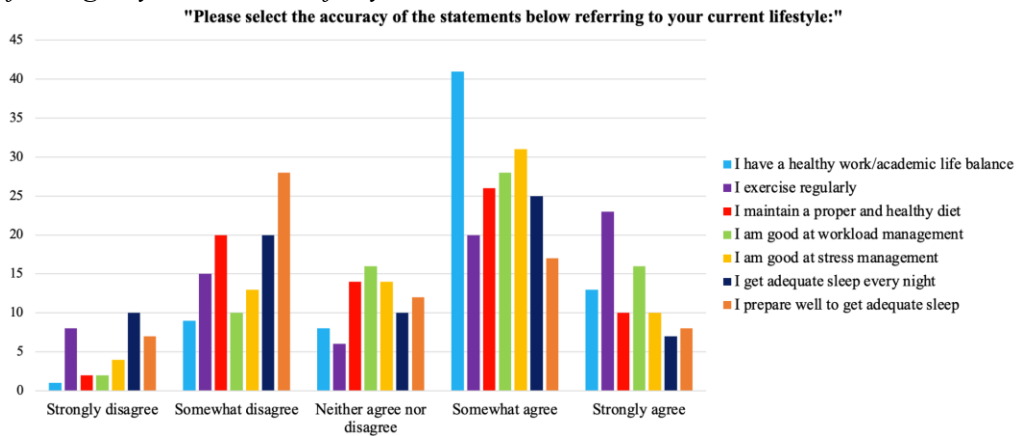


Figure 2

Answer Distributions to “Please select the accuracy of the statements below referring to your academic program, life, and experiences:”

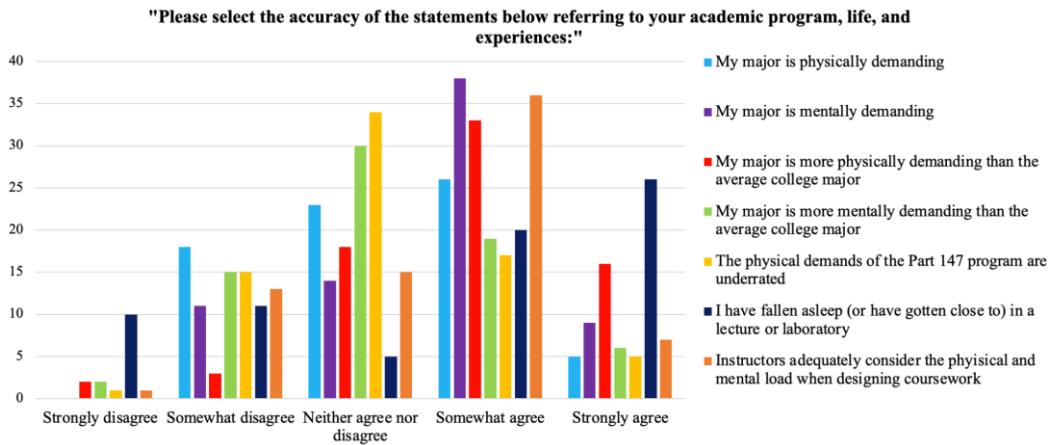


Figure 3

Answer Distributions to “Please select the accuracy of the statements below referring to your academic program, life, and experiences:”

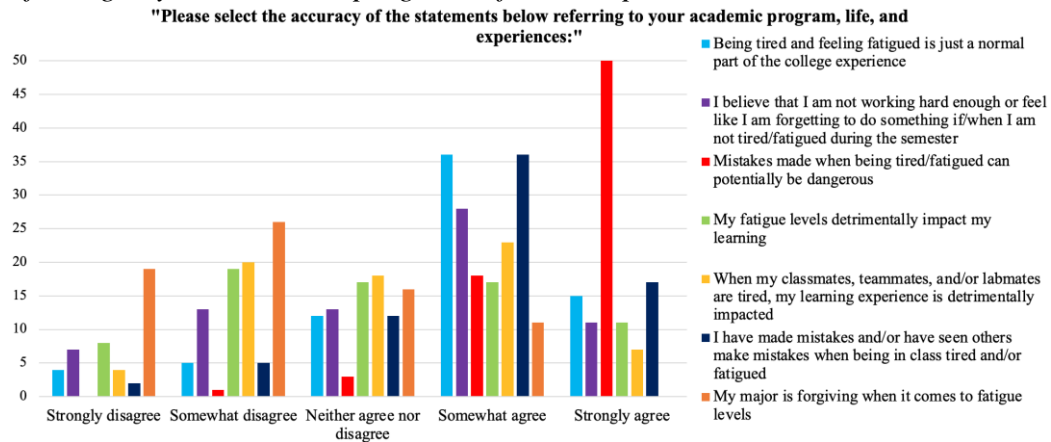


Figure 4

Answer Distributions to “Please select the applicable frequency of the statements below referring to your academic program, life, and experiences:”

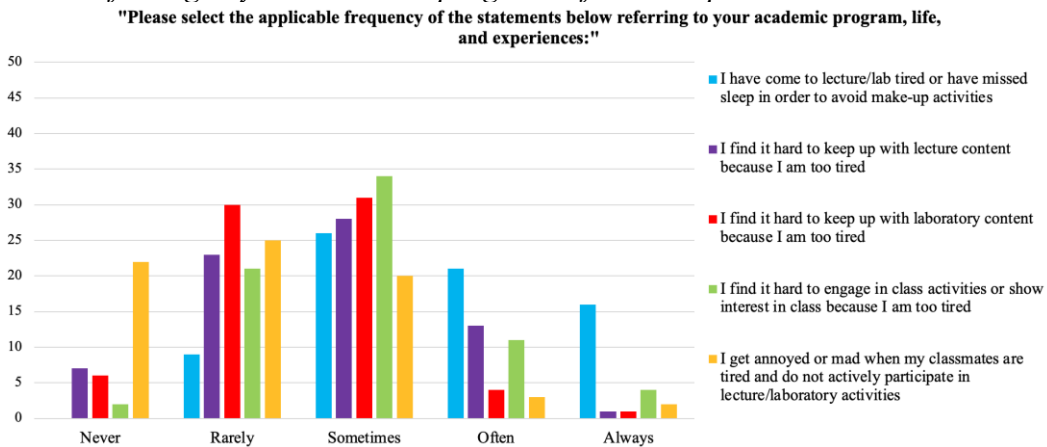
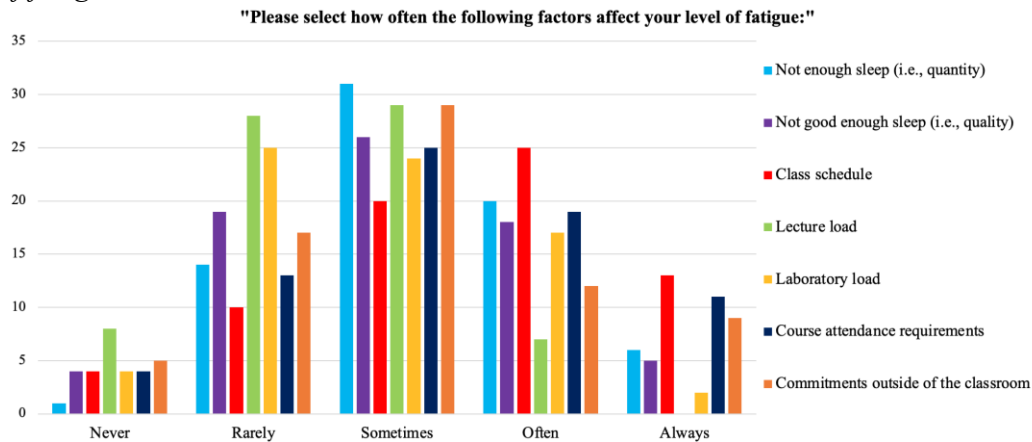


Figure 5

Answer Distributions to “Please select how the following factors affect your level of fatigue:”



Discussion and Key Takeaways

Sleep is commonly the first thought of fatigue-influencing factor. As a general and well-known rule, adults are usually recommended to sleep between six and eight hours, or even between seven to nine hours. From the responses obtained (refer to Table 4), it can be seen that approximately 40% of the respondents fail to obtain the minimum recommended amount of sleep. While one could argue that the majority of the respondents still get an adequate amount of rest, 40% is a concerningly large percentage of the surveyed population. These results further fall in line with the findings presented in literature both for collegiate flight students and professional maintenance technicians which indicated a lack of sleep and a sleep debt above the national average, respectively (Avers & Johnson, 2011; Avers, 2015; Levin et al., 2019; Romero et al., 2020; Teo, 2020). Nevertheless, these results are not fully reflected in the responses to the survey where participants were asked to rate their sleeping habits more subjectively. For instance (see Figure 1), there is a comparatively even split in responses along the *strongly disagree - strongly agree* spectrum to the statements “*I get adequate sleep every night*” and “*I prepare well to get adequate sleep.*” While these splits somewhat mimic the 40% of the responses indicating sleep quantities below the recommended, it is interesting to highlight that merely seven participants (slightly below 10% of the respondents) fully believe that they receive adequate sleep quantities. By extension, the percentage of participants indicating that they prepare well to sleep is lower than those indicating that they do not take adequate procedures to prepare to sleep. Similarly, when rating the impact of sleep (or lack thereof) on their fatigue levels, a comparatively even split is observed along the *never-always* response scale (see Figure 5), somewhat reflecting the sleeping trends introduced above and in Table

4. However, even though based on the results shown in Table 4 circa 60% of the respondents should be receiving sufficient sleep, merely 15 and 23 participants (equivalent to 20% and 32% of the respondents) indicate that their sleeping habits, in quantity and quality of sleep, respectively, rarely to never influence their fatigue. In other words, even though the majority of the surveyed students claim that they sleep at levels above the recommended minimum for adults, only a minority indicates sufficient or adequate sleep with minimal to no detrimental impact on their fatigue levels.

Moreover, as stressed by Levin et al. (2019), Mendonca, Keller, and Lu (2019), Romero et al. (2020), and Teo (2020), sleep does not necessarily have to be the only factor that affects students' fatigue levels, especially in an aviation environment. Such additional factors are explored in Figures 1 through 5, and include components more general to the college experience as well as elements more unique to Part 147 (i.e., AMT) educational programs. The results obtained, however, are not completely reflective of the results obtained in flight student-specific literature. When it comes to factors such as work/academic life balance, healthy lifestyle (including exercise and diet) as well as workload and stress management (as shown in Figure 1) the responses from aviation maintenance students indicate that these students have comparatively good habits and have the tools to handle the challenges presented by the collegiate environment. While a minority of the responses do indicate some degree of struggles or difficulty therewith, a large percentage of the participants provide promising results. To evaluate, thus, which factors do impact the fatigue levels of Part 147 students, the results from Figure 5 can be used. While the impact of sleep habits has already been discussed and presented above, the additional factors also need to be considered. In this case specifically, it appears that factors other than sleep actually contribute more to the fatigue levels of aviation maintenance technician students.

Specifically, the top three factors identified by students are commitments outside of the classroom, course attendance requirements, and the schedule of classes. Both, outside of class commitments and class schedules have also been mentioned by Mendonca, Keller, and Lu (2019). However, within the context of flight training, these elements appeared to not be as prevalent as for maintenance students. It is important to highlight, moreover, that the factor "class schedule" is different than the course (i.e., lab and lecture) load. While the load of classes refers to the quantity of lectures and laboratories, the schedule refers to the organization and distribution thereof throughout the day. As such, participants did not indicate issues with the course load itself, but with how said classes and laboratories are distributed and scheduled throughout the day. The third factor, course attendance requirements, is a point of contention frequently discussed within the context of Part 147 education. Specifically, the FAA mandates and regulates very specific attendance requirements. On one hand, as previously introduced, a number of

classroom or instructional hours need to be completed by students in order to qualify for the certification examination (Title 14 C.F.R. § 147.21, 1992). While new guidelines were developed to move away from the hour-based attendance requirement (Aviation Maintenance Technician Schools, 2022), current Part 147 students, such as the ones surveyed, have been required to meet the older requirements set under Title 14 C.F.R. § 147.21 (1992) until the recent change. Among others, these included comparatively strict absence policies and subsequent make-up activities (FAA, 2015). The impact from the FAA-regulated attendance requirements is also shown in Figure 4, noting the responses to the following statement: *“I have come to lecture/lab tired or have missed sleep in order to avoid make-up activities.”* Through the responses obtained, it can be seen that the strict attendance requirements and related make-up activities have contributed to students’ tiredness and fatigue. Not a single participant indicated that the attendance requirements, or more precisely, the intent to avoid the make-up activities required when missing a class, have never impacted their sleep/tiredness. Moreover, slightly over half of the participants, namely, 37, responded with *“Often”* or *“Always”* to the statement in question. It will be interesting to observe if (and if so how) the responses to this question will (or would) change once the new regulations with the revised attendance and hour-based requirements (Aviation Maintenance Technician Schools, 2022) are enacted and trickle through the system.

Additional factors that contribute to students’ fatigue levels, as provided through a free response option are shown in Table 5 above. Here as well, commitments outside of the classroom are indicated in the form of family/relationship obligations, military duties, jobs, and extracurriculars. While additional factors are also indicated in the free response option, these are comparatively individualistic, and include mental health, indications of seasonal affective disorder, and being away from home. These results can thus be tied back to the fatigue definition by Phillips (2015), which highlighted and reinforced that a range of individual factors and characteristic influence one’s fatigue, making each individuals’ experience different and unique.

In Figure 2, results more specifically related to the Part 147 educational program are introduced. The statements provided therein aimed to provide more background information on the AMT program and factors thereof that may contribute to student fatigue levels. As previously introduced, the Part 147 educational programs heavily rely on hands-on education, where students participate in laboratory activities almost daily and are required to actually perform a series of maintenance tasks. As such, some degree of physical exhaustion might be expected. The results (as shown in Figure 2) present a certain level of duplicity. On one hand, participants indicated experiencing greater mental demands than physical demands. On the other hand, the responses reflect that maintenance

students understand that their degree is more physically demanding (yet, not as mentally demanding) as other college degrees.

By extension, an approximately 50-50 split is observed along the *strongly disagree-strongly agree* scale for the statement “*The physical demands of the Part 147 program are underrated,*” with the mid-value “*Neither agree nor disagree*” receiving the most responses. These results may indicate that AMT students acknowledge the physical demands of their program, but do not believe that the physical demands are overwhelming (to a certain degree). Similarly, not being as mentally demanding as other programs is, in this case, not equivalent to the Part 147 program being effortless or simple. Moreover, it is possible to praise the Part 147 instructors, as the majority of students believe that instructors consider the course load adequately when preparing the course (see Figure 2). This last factor, thus, can be combined with the above-indicated distinction between course load and course scheduling. Rather than there being an inherent issue with the course load overall or the load in individual classes, the scheduling thereof is being contented.

While in Figures 1 and 5, as well as in the paragraphs above, the factors related to fatigue were introduced and discussed, the results shown in Figures 2 through 4 focus more specifically on the levels of fatigue and the consequences thereof. As shown in Figure 2, 46 respondents (i.e., approximately 64% of the participants) indicated some form of agreement (i.e., either somewhat or strongly agree) to the statement “*I have fallen asleep (or gotten close to) in a lecture or laboratory.*” From these responses, it is possible to infer that there is some factor that influences students’ ability to stay alert and present in the classroom. Further research that is more centered on pedagogy or fatigue from a medical perspective might be needed to better understand why students fall asleep in the classroom. Nevertheless, it is interesting to point out that the majority of students should be getting enough sleep based on the self-reported sleep hours (see Table 4). Therefore, theoretically, a lack of sleep (quantity) should not be a major cause for students falling asleep while in a lecture or laboratory session. However, as previously indicated, a large proportion of the participants indicated not receiving sufficient sleep, with detrimental impacts on their fatigue levels. As such, this discrepancy between time slept and rest obtained therefrom may provide some explanation to the fact that a majority of the surveyed maintenance students have, or have gotten close to, falling asleep in class. As outlined previously, nonetheless evaluating these factors and the causes thereto falls outside of the scope of the research study and the researchers’ expertise.

The consequences of fatigue and tiredness, as mentioned in previous sections, do not end at falling asleep in public spaces (or falling asleep in the classroom, in this case). Two other factors to consider are the quality of the educational experience, with the hypothesis, per Phillips’ (2015) definition and the

literature findings, that it would decrease with increasing fatigue levels, as well as the safety in the educational laboratories. The perceptions of the surveyed Part 147 students on these two specific aspects are shown in Figure 3. From the responses, it is possible to ascertain that students are aware of the safety risks associated with elevated levels of fatigue. A total of 50 participants (equivalent to approximately 68% of the responses) indicated that they believe that mistakes made due to fatigue can be dangerous. These results are promising, as they reflect that Part 147 students are at least aware of the dangers associated with working fatigued in the aviation maintenance environment. However, the responses are also concerning when a different statement is considered. As indicated by the dark blue bars in Figure 3, it can be seen that a large proportion (the majority) of the respondents, whether that be through their own or second-hand experience, have seen mistakes occur due to fatigue. These results further reinforce the notion that in current Part 147 instructional spaces mistakes occur because students are not sufficiently well-rested and are subsequently fatigued in the classroom.

When it comes to the impact of fatigue on learning, a wide distribution in the responses can be seen. As shown in Figure 3, for both statements “*My fatigue levels detrimentally impact my learning*” and “*When my classmates, teammates, and/or lab mates are tired my learning experience is detrimentally impacted*” responses along the spectrum are approximately evenly distributed. One potential explanation therefore may be that the effect on the learning experience is somewhat dependent on each individual and their personal learning preferences, so that no overarching trend can be recognized. Similar trends, if not more extreme towards the rarely-to-never end of the spectrum and a large proportion of the answers being in the middle of the spectrum, can be recognized for questions with similar themes shown in Figure 4. Keyed in purple, red, and green, participants indicated that class participation and engagement as well as following along with laboratory and lecture content were not greatly influenced by their levels of fatigue. Similarly, even if classmates are fatigued and thus their participation is hindered, the respondents mostly indicated no resentment or annoyance towards them.

Lastly, the survey included two questions aimed at ascertaining students’ perceptions with regard to toxic ideas and notions common to upper education and collegiate environments. The two statements are: “*Being tired and fatigued is just a normal part of the college experience*” and “*I feel like I am not working hard enough or feel like I am forgetting to do something if/when I am not tired/fatigued during the semester.*” The responses thereto are highlighted in Figure 3, where a slight general trend towards the agree-end of the spectrum can be discerned. While further dissection of these statements, the associated responses, and the toxicity in the collegiate environment together with the effects thereof require further research outside of the scope of this study, the results do indicate a concerning trend.

Conclusion, Limitations, and Potential for Future Work

The conducted research project and associated survey aimed to better understand and explore the fatigue-related factors, influences, and effects for Part 147 students in an aviation maintenance school in the United States. Based on the results, fatigue was identified as a crucial factor that requires further attention when developing or adapting Part 147 educational programs, especially from a safety perspective. Overall, the surveyed students appeared to present adequate sleeping patterns and healthy lifestyles coupled with good work-life balances and the ability to properly manage their workload. Yet, fatigue themes still emerged as the participants expressed general themes of tiredness and less-than-perfect sleep quality. Similarly, students falling asleep while in class as well as committing errors and mistakes due to fatigue were reported. When investigating fatigue-causing factors, three themes emerged: commitments outside of the classroom, the schedule of classes, and course attendance requirements. Especially the latter course, attendance requirements, is critical, given that these attendance requirements have been, until recently, strictly controlled by the FAA. However, changing regulations may affect how course attendance requirements affect the fatigue levels of aviation maintenance students. In terms of the consequences of being fatigued in the classroom, the safety hazards associated with fatigue seemed to be well understood, while the participants indicated that the fatigue levels did not have a detrimental impact on the actual learning process itself. Lastly, based on specific questions, concerns regarding internalized toxic thoughts related to fatigue in a collegiate environment emerged, which the researchers believe are crucial to be considered or studied in the future.

Even though the survey provided significant insight into Part 147 students' fatigue experience and beliefs, it is similarly important to acknowledge certain limitations of the research instrument. First of all, the survey relied on students' self-reported beliefs and thoughts. Thus, the responses are subjective and may vary with the participants' interpretation of the questions as well as their own biases. Moreover, fatigue and its related topics and patterns can be sensitive subjects which students may feel guilty or vulnerable admitting to. Especially with questions related, but not limited to, sleep schedules, lifestyles, or the impact of class load/requirements, students may have had the impression that they either could not be truthful or were not honest with themselves when answering. As such, participants may have felt the urge to provide the "correct" or "expected" answer rather than the true, real, or more vulnerable response. Furthermore, the survey was primarily based on rating-type questions, with only one free-response question. However, the topic of fatigue is intricate and, consequently, the rigid format of the survey may not be the most adequate method of collecting information on such a complex subject. Lastly, the specific sample itself does include an inherent limitation – namely, that all respondents are from one and the same educational

institution. Therefore, the results may be impacted by the specific academic/educational culture of the institution sampled and limited in terms of representativeness or applicability to all aviation maintenance students.

Considering the results, conclusions and limitations described above, a range of directions for future research can be devised. The research conducted served as an initial survey, and thus, did not separate the results obtained by demographic characteristics such as age, gender, or class ranking, among others. However, as shown by Keller et al. (2021) and Teo (2020), these factors may have an impact on fatigue behaviors. Therefore, future research could focus on the impact of specific demographic factors. Similarly, since the survey was distributed at a single institution, future research could focus on expanding the reach of the survey to more AMT programs/schools across the United States, with the intention of obtaining more representative findings or note whether differences between programs emerge. Furthermore, interesting themes and questions that are noteworthy and merit their own studies emerged. The first question refers to evaluating as to why students struggle staying awake and attentive in class even when sleeping more than the minimum recommended for adults. Secondly, the impact of the changing requirements by the FAA for Part 147 students (i.e., changing from hour-based to competency-based programs) on students' fatigue (given that the attendance requirements were listed as influencing factors) could be studied when the new regulation is settled. Lastly, the hints of toxicity and toxic culture as it pertained to the "expected" or "normal" fatigue levels in a collegiate environment that were received from the respondents should be addressed in future research.

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Appendix

Demographic Questions

- 1. Please insert your age in numerical format:**
- 2. Please provide the gender identity that best describes you (optional):**
- 3. Please select your major(s):**
 - a. Aeronautical Engineering Technology (AET)
 - b. Professional Flight
 - c. Aviation Management
 - d. Unmanned Aerial Systems (UAS)
 - e. Other
 - f. I am no longer a student
- 4. Please select your class standing:**
 - a. Freshman
 - b. Sophomore
 - c. Junior
 - d. Senior
 - e. Combined degree student (i.e., “3+2”)
 - f. Graduate student
 - g. I am no longer a student
- 5. Are you part of a Part 147 program (i.e., “A&P program”)?**
 - a. Yes
 - b. No
- 6. How long (in years) have you been part of the Part 147 program (Please provide your answer in a numerical format)?**
- 7. Do you plan on pursuing your A&P?**
 - a. Yes
 - b. No
- 8. Select the accuracy of the statements below referring to your current lifestyle.**

Scale:

Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
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Statements:

- I have a healthy work/academic life balance
- I exercise regularly
- I maintain a proper and healthy diet
- I am good at workload management
- I am good at stress management
- I get adequate (i.e., quantity and quality) sleep every night
- I prepare well to get adequate sleep

9. How many hours do you sleep, on average, each day while classes are in session?

- 0-2 hours
- 2-4 hours
- 4-6 hours
- 6-8 hours
- 8-10 hours
- 10+ hours

10. Select how often the following factors affect your level of fatigue

Scale:

Never	Rarely	Sometimes	Often	Always
(1)	(2)	(3)	(4)	(5)

Statements:

- Not enough sleep (i.e., quantity)
- Not good enough sleep (i.e., quality)
- Class schedule (Including early/late classes and/or no breaks)
- Lecture load (i.e., number of lectures)
- Laboratory load (i.e., number of laboratory sessions)
- Course attendance requirements
- Commitments outside of the classroom (i.e., family, jobs, clubs, social activities, etc.)

11. Please list any further factors - other than the ones mentioned above - that add to your fatigue levels:

12. Select the applicable accuracy of the statements below referring to your academic program and academic life/experience:

Scale:

Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
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Statements:

- My major is physically demanding
- My major is mentally demanding
- I have fallen asleep (or have gotten close to falling asleep) in a lecture or laboratory
- My major is more physically demanding than the average college major
- My major is more mentally demanding than the average college major
- Instructors adequately consider the physical and mental load when designing coursework
- Being tired and feeling fatigued is just a normal part of the college experience
- Mistakes made when being tired/fatigued can potentially be dangerous
- The physical demands of the Part 147 program are underrated
- My fatigue levels detrimentally impact my learning
- When my classmates/teammates/lab mates are tired, my learning experience is detrimentally impacted
- I believe that I am not working hard enough or feel like I am forgetting to do something if/when I am not tired/fatigued during the semester
- I have made mistakes and/or have seen others make mistakes when being in class tired and/or fatigued
- My major is forgiving when it comes to fatigue levels - i.e., it does not make a difference whether I come to class tired or well-rested

13. Select the applicable frequency of the statements below referring to your academic program and academic life/experience:

Scale:

Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
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Statements:

- I have come to lecture/lab tired or have missed sleep in order to avoid make-up activities
- I find it hard to keep up with lecture content because I am too tired
- I find it hard to keep up with laboratory content because I am too tired
- I find it hard to engage in class activities or show interest in class because I am too tired

- I get annoyed or mad when my classmates/teammates/lab mates are tired and do not actively participate in lecture/laboratory activities