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An Exploration of the Relationship Between Flight Simulator Performance and Achievement of Solo Flight Among Australian Aviation Students

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University flight training programs are becoming an increasingly important avenue for developing ab initio pilots, yet training programs suffer high attrition rates. Flight simulators are commonly used by university flight schools as a training aid, and the purpose of this research is to understand if student performance using a Personal Computer-Based Aviation Training Device (PCATD) is a relevant predictor of student success as measured by the achievement of flying solo in university flight training. To investigate this, 195 students at an Australian university from 2018 to 2021 were subject to comprehensive flight simulator instruction via a PCATD prior to flight training, with simulator performance correlated to flight training success. This sample was split into international and domestic students, with the PCATD performance of each group correlated to the achievement of the first solo and the number of flight hours to the first solo, respectively. Results suggested that international students who achieved the first solo had better simulator performance on average than those who did not. However, a statistically significant relationship was unable to be observed between flight simulator performance and flight time to achieve solo flight amongst domestic students.

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Introduction

The decision to embark on flight training represents a considerable investment of time and money from the student and flight training institutions alike (Lutte & Mills, 2019). This resource demand, coupled with the competitive nature of the pilot profession, limited training positions (Lutte & Mills, 2019), and trends of fewer students completing university pilot training (United States Government Accountability Office, 2014), emphasizes the need for effective candidate selection. To assist with identifying suitable prospective candidates, an array of testing methods are employed by flight training institutions to varying degrees of success. The imperfect nature of pilot selection is highlighted by flight university attrition rates, with reports of between 30% (Bjerke & Healy, 2010) and as high as 70% (Peppler, 2011, as cited in Emery, 2011). Flight simulators are commonly used by university flight schools (Goetz et al., 2015), often as a preparatory aid prior to offering official flight training. The training benefits of simulators are widely accepted in aviation, but limited information exists on simulators as a tool to assess the likelihood of student success in university flight training. The purpose of this study was to better understand the relationship between simulator performance and student success in university flight training.

Literature Review

Pilot Selection

Historically, the pilot selection process has developed alongside the aviation industry. An understanding of the favorable personal attributes of pilots has been sought by training institutions as early as World War I and has continued ever since, with pilots enduring as one of the most tested modern professions (Martinussen & Hunter, 2017). Current global aviation training trends are seeing tertiary education playing an increasingly important role in training ab initio pilots, particularly in the civil sector (Lutte & Mills, 2019).

The conventional performance metric to predict student performance at university has been past academic success (Jones, 2013; Zierke, 2014). This aspect is consistent with tertiary flight training, where the grade point average (GPA) has been found to be a valid indicator of future training success in some aspects of flight training (Jones, 2013; McFarland, 2017). Jones' (2013) study of 264 participants found a statistically significant relationship between GPA with the length of time to complete an instrument rating and instrument rating flight test pass rate. A higher GPA was shown to reduce the time taken to complete the rating and the number of flight test attempts required to pass. However, GPA was not found to relate to either length or time to complete or the flight test pass rate for a private rating, nor the number of flight hours to complete either a private or instrument rating.

Whilst GPA makes use of available academic data, some research has been conducted using supplementary testing measures seeking to measure specific attributes. One such attribute is perceptual speed, defined as the "speed of processing information and the ability to focus attention" (Mekhail et al., 2010, p. 106), and is measured using a table reading test or table speed test (Mekhail et al., 2010; McFarland, 2017). A study of 116 participants at a major American university found that perceptual speed could be used to predict time to solo and flight time to achieve a private pilot certificate (Mekhail et al., 2010). However, this finding failed to be replicated by a similar study of 69 participants, where no statistically significant relationship was found between these variables (McFarland, 2017).

Flight Simulators and University Flight Training

Another potential avenue to predict student performance in university flight training is using work sample tests, which are among the best predictors of future performance in flight (Martinussen & Hunter, 2017). A work sample test endeavors to recreate an environment that replicates on-the-job performance; for pilots, a work sample test is typically administered by a simulator (Hoermann & Goerke, 2014). Simulators have been a part of aviation since the Link "blue box" trainer was developed in 1929 (Ennis, 2009). NASA's Apollo missions also accelerated advancements in simulator technology, leading to the current range of sophisticated systems (Page, 2000), with these high-fidelity simulators typically the domain of military and airlines (McDermott, 2005). The advancement of computer technology through the 1990s lead to the rise of Personal Computer-Based Aviation Training Devices (PCATDs) (Martinussen & Hunter, 2017; McDermott, 2005), which function as rudimentary versions of the high-fidelity simulators (Ennis, 2009). Extensive research on PCATDs, now generally referred to as Flight Training Devices (FTDs), has found that despite the lower fidelity, they are still effective training aid (Martinussen & Hunter, 2017). One method to evaluate PCATD effectiveness was using a concept of training effectiveness ratio (TER). TER is defined as "the degree to which hours in the simulator replace hours in the aircraft" (Roscoe, 1980, as cited in Martinussen & Hunter, 2017). For example, a TER of 1.0 means every hour in the simulator saves an hour of flight time. Similarly, a TER of 0.5 means every hour in the simulator saves a half hour of flight time.

The training and cost-effectiveness of PCATDs have seen wide-scale adoption by tertiary institutions to supplement flight training (Goetz et al., 2015). In a university flight training setting, PCATDs have been shown to achieve positive TERs ranging from 0.12 up to 0.28 (Taylor et al., 1999, as cited in Martinussen & Hunter, 2017). PCATD training was found to decrease the flight hours prior to the first solo and landings prior to the first solo in some ab initio students prior to commencing flight training (Vaden et al., 1998). Also, a study of 14 participants from the beginning of university flight training found that those using the PCATD performed better than the control group on average, but the difference was not statistically significant (Olson, 2002).

Research Questions and Hypotheses

The aim of this research was to further explore the relationship between simulator test grade (STG) performance and flight training proficiency through the lens of two research questions:

> Research Question 1 (RQ1): How does an international university aviation student's STG relate to the likelihood of the eventual achievement of solo flight?
>
> Research Question 2 (RQ2): How does a domestic university aviation student's STG relate to the number of flight hours accrued prior to achieving solo flight?

These research questions are aligned with the following hypotheses:

> The null hypothesis for RQ1 ($H1_0$): There is no significant difference in STG between students who later achieved solo flight and those who did not.
>
> The alternative hypothesis for RQ1 ($H1_A$): There is a significant difference in STG between students who later achieved solo flight and those who did not.
>
> The null hypothesis for RQ2 ($H2_0$): There is no correlation between STG between students and the number of flight hours accrued prior to achieving solo flight.
>
> The alternative hypothesis for RQ2 ($H2_A$): There is a correlation between STG between students and the number of flight hours accrued prior to achieving solo flight.

Methodology

Design and Sample

This study was quantitative in nature and utilized a sample of university students at a major Australian university to represent tertiary aviation education students in Australia. Eligible participants must have completed a 13-week first-year university simulator subject between 2018 and 2020 and received an STG, as well as undertaken flight training up to at least the point of the first solo.

To answer the research questions, the sample was subdivided into two groups, international and domestic flight training students, which was necessary due to differences in the nature of flight training pathways at the university. After completing the first-year simulator subject, international students were automatically permitted to enroll in a basic flight training course (allowing them to train up to and possibly including solo flight) approximately four to six months after completing flight training. Conversely, domestic students completed a rigorous application process to commence Commercial Pilot Licence training approximately one year after receiving their STG. While flight training pathways differed for international and domestic students administratively, the training content remained the same, allowing both groups the opportunity to progress to solo flight.

Data Collection

This protocol was approved by the university's Human Research Ethics Committee. Data were extracted from existing university student records, collated, and deidentified prior to analysis. No personal information was recorded in the data set, which included only STG scores and solo flight outcomes. STG data was obtained from the first-year simulator subject grade books between 2018 and 2020, corresponding to three full cohort cycles, and was applicable to both sample groups. The flight simulator used to administer training and assess the STG was a desktop PCATD that replicates a Cessna C-172 aircraft using Lockheed Martin Prepar3d software. The PCATD hardware comprises a visual display coupled with force feedback controls consisting of a desktop yoke and throttle quadrant with floor-mounted rudder pedals. The STG was a numerical value out of 20 and was based on a student's manual handling and procedural compliance while flying a circuit from take-off to landing (or go-around).

Data related to solo flying used to answer RQ1 and RQ2 differed due to how the university recorded progress for the two groups. For international students, only a fixed training block of flight hours was available, and training was concluded once the hours had elapsed, whether the solo flight was achieved or not. For domestic students, an hourly limit was not enforced. Hence for the purpose of this study, training success was defined by the number of flight hours required to achieve the first solo. This impacted the data that was collected: for international students, only data on whether a solo flight was achieved as part of their undergraduate flight training subject was recorded. For domestic students undertaking Commercial Pilot License training, university records included the number of flight hours students required to achieve solo flight, which was extracted for RQ2.

Method

For RQ1, an analysis of variance (ANOVA) was performed on the international student data to determine any difference in the mean STG between the students who achieved solo and those who did not. Means and standard deviations for STG scores were compared between students who were ultimately able to achieve solo flight and those who were not. For RQ2, single linear regression was used to explore any relationship between domestic students' STG and corresponding flight time to first solo as measured by flight hours.

Results

Data from 195 students were included in the study, covering124 international students and 71 domestic students. Sample descriptive statistics relating to STG scores and solo performance are displayed in Table 1.

Table 1
Sample descriptive statistics

	International students (N = 124)		Domestic students (N = 71)	
Variable	N	%	N	%
Solo status				
Yes	46	37.1	71	100
No[a]	78	62.9	0	0
	Mean	SD	Mean	SD
STG – yes solo	15.78	2.48	15.15	2.54
STG – no solo[a]	13.65	2.49	-	-
Time to solo[b] (hr)	-	-	20.10	5.86

[a] Domestic students must have flown solo to be considered
[b] Data not considered for international students as outside the scope of this study

Research Question 1

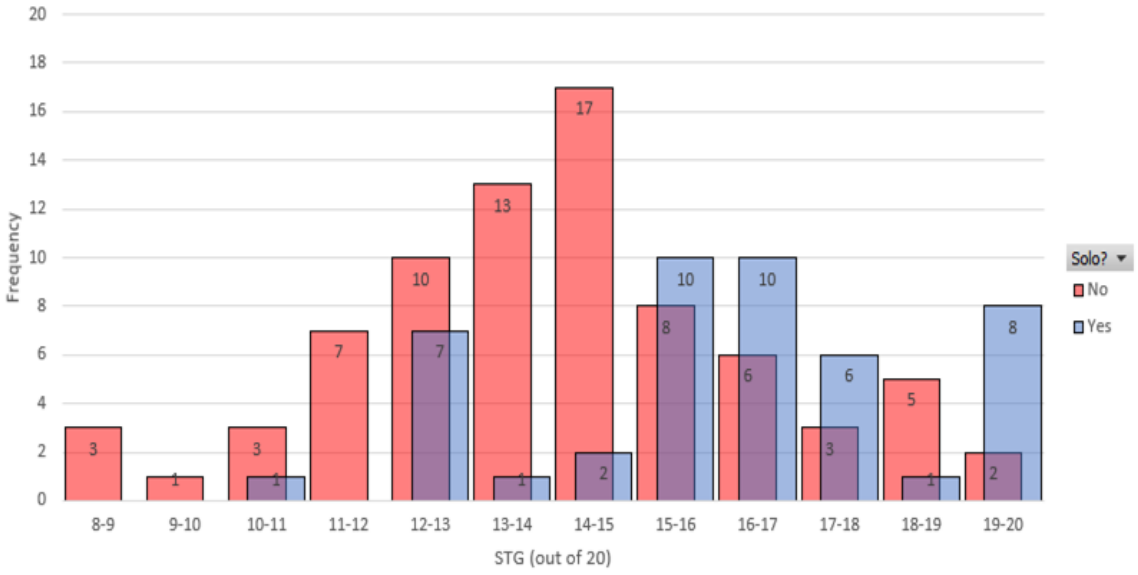
Of the 124 international students in the data set, 78 were unable to achieve solo flight compared to 46 who were. Within these groups, Shapiro-Wilk tests of normality yielded p-values of .133 and .113, respectively, suggesting normality. Additionally, standard errors of 2.49 and 2.48, respectively, yielded a Levene statistic of .000, corresponding to $p<.989$, suggesting equal variances. As shown in Table 2, international students who did fly solo averaged STG scores of 15.78/20, compared to 13.65/20 for those who did not. This variance corresponded to an F-value of 21.19 and a p-value of <.001.

Table 2
International Student ANOVA Results

	International students (N = 124)	
Variable	M	Var
STG – yes solo	15.78	6.15
STG – no solo	13.65	6.21
F value	21.19	
P value	1.03×10^{-5}	
F crit	3.92	

A histogram for comparative visualization of international student data is displayed in Figure 1.

Figure 1
Histogram of STG vs. Solo flight status for international students



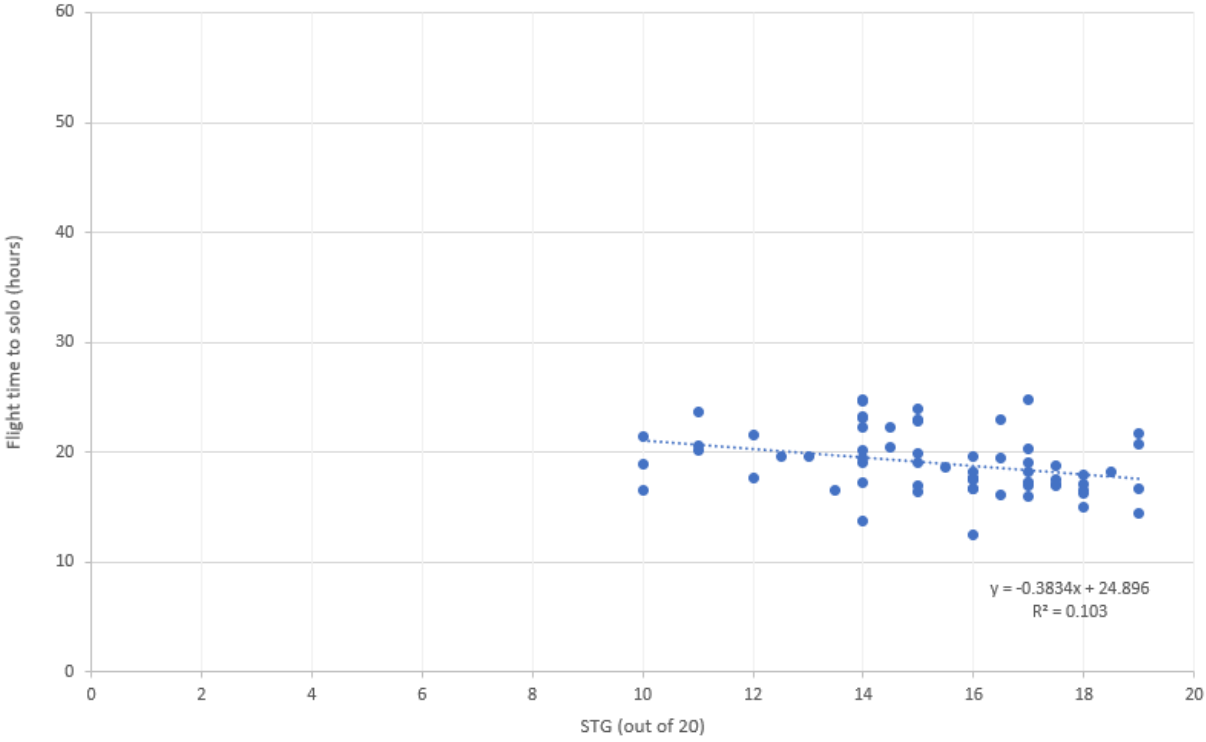
Research Question 2

A linear regression was performed on the domestic student data to explore the relationship between STG and flight time to solo. The descriptive statistics and regression results are displayed in Table 3 and visually displayed via scatterplot (Figure 2). The sample was subsequently analyzed for outliers. Values residing outside 1.5 times the upper or lower interquartile range (IQR) for either variable were deemed outliers. A linear regression was performed with the outliers removed. The subsequent descriptive statistics are displayed in Table 3 and visually displayed via scatterplot (Figure 2).

Table 3
Domestic student descriptive statistics and regression results

	Domestic students (N = 71)		Domestic students – outliers removed) (N = 64)	
Variable	Time to solo	STG	Time to solo	STG
Mean	20.10	15.15	19.00	15.37
Median	18.90	15.50	18.65	16.00
SD	5.86	2.54	2.81	2.35
IQR	4.70	3.00	3.68	3.00
R^2	0.0464		0.103	
R	-0.215		-0.321	

Figure 2
Plot of STG vs. flight time to solo for domestic students – no outliers (N = 64)



Discussion

Strong findings from research RQ1 show that international students with better simulator performance are more likely to achieve solo with a fixed-time training syllabus. With successful students achieving a mean STG of 15.78 and unsuccessful students achieving a mean STG of 13.65, the analysis found a statistically significant difference in simulator performance based on whether students were later able to achieve solo flight. The analysis demonstrates a statistically significant correlation (P-value < 0.05) between STG and attainment of the first solo for international students, therefore rejecting the null hypothesis.

For RQ 2, results of the linear regression analysis indicated a weak negative linear relationship between STG and flight time to solo in domestic students ($R = -0.215$, $R^2 = 0.0464$), indicating that the STG explains 4.64% of the variability in flight time to first solo. The sample was re-analyzed after the identification and removal of outliers. This strengthened the correlation slightly, but overall, it remains a weak negative linear relationship ($R = -0.321$, $R^2 = 0.103$), indicating that the STG explains 10.3% of the variability in flight time to the first solo. While a negative correlation was observed between STG and flight time to first solo, there was not sufficient evidence to demonstrate statistical significance at an alpha level of .05, and as a result, the null hypothesis for RQ2 could not be rejected. Although the results for RQ2 were unable to statistically demonstrate previous findings that PCATD training decreases flight hours prior to the first solo (Vaden et al., 1998), they are consistent with findings from Olson (2002).

The strengths of this research are the methodology accounts for the differences in training experience between domestic and international students through discrete samples, with a subsequent independent statistical analysis of each. This allows the unique external factors influencing each group to be contained, helping to limit cultural effects so as to not skew results, allowing for a clearer view of the relationship between flight simulator performance and training outcomes. The considerable total sample size obtained (n = 195) has allowed for statically significant conclusions to be drawn.

Limitations

Research data were curated from existing data, originally collected for teaching and learning purposes. As such, this prevented control over data collection methods and potential confounding variables. The dataset yielded strong evidence from RQ1 and suggested that international students with better simulator performance were more likely to achieve solo with a fixed-time training syllabus. While this relationship was not statistically demonstrable for domestic students, data did reflect the same general trend of better simulator performance being related to reduced flight training hours to solo flight. The failure of this relationship to be observed with statistical significance in this study may have been due to differences in the flight training circumstances of international and domestic students. One key difference in these training pathways is the time interval between when domestic students undertook simulator training and when their practical flight training began. This data was not gathered or accounted for in this study, which for domestic students is approximately one year. International students, however, commenced their practical flight training course within four to six months after completing the simulator training. It is possible that these delays had an appreciable impact on the strength of findings, as benefits of PCATD training and any skills acquired may have eroded due to the delay, a phenomenon that is well understood in the aviation industry (Martinussen & Hunter, 2017), with inexperienced pilots particularly susceptible (Childs & Spears, 1986). Also, given the comparatively modest TER of PCATD, the skills developed may be less robust than other training methods and may deteriorate against a time delay. This effect may have been further exacerbated through other delays resulting from COVID in 2019, 2020, and 2021 cohorts, along with other traditional contributors to flight training delays, such as weather. In addition, the research only consisted of univariate analysis, and additional factors such as grade-point average (GPA) or participant age were not considered. GPA is a particular factor of interest, as STG may just be a proxy for GPA, and research results are consistent with the previous studies on flight training and GPA (Jones, 2013). Also, whilst a comparatively large sample for this type of study was obtained, it was nonetheless a convenience sample, and this may limit the generalization of research findings to the wider university flight training environment.

Different levels of motivation may also have played a role in performance. International students only had one opportunity to complete their flying course, whether they were able to fly solo or not, and whether students flew solo impacted their ability to continue training independently. A limitation specifically relating to RQ1 is that some students who failed to fly solo may have been limited by the syllabus hour cap and may not have necessarily been a reflection of an inability to achieve solo without further flight hours. Domestic students had greater flexibility in the pace of their training and undertaking remedial flights, which may have affected the pressure on them to perform. These differences in the training circumstances of the

two groups may also help explain the overall lower average time to fly solo for international students. Further research can address these factors to unpack the nature of the relationship between simulator performance and practical performance in a flight training context.

Further Research

Key future research avenues of interest concern better understanding the effects of delays between the simulator and commencement of training, reviewing additional prediction methods using simulator performance, better understanding the challenges of flight training as an international student, and multivariate analysis.

Firstly, an investigation into the effect of conducting simulator training closer to the commencement of flight training would help understand the effect of delay between commencement between events. Potentially the more marginal TER of PCATD simulators sees a less sustained training benefit that erodes after a significant delay period, as was the case in this study.

Another potential area of research interest could be to explore other variables that describe simulator performance to further unpack its predictive ability as well as other aspects of training that simulator proficiency can impact. One approach could be to explore the influence of simulator performance on the achievement of various flight training milestones within a certain amount of flight time. Another avenue could be to measure other aspects of simulator performance (such as time to master maneuvers, decision-making capacity, or communication skills) to establish any predictive quality they may offer.

It is noteworthy that only 37% of the international student cohort did successfully complete a solo flight. As to the remaining 63%, further research can explore why the solo flight was unachievable, considering this group still managed to achieve a passing STG. This could in part due to the unique challenges are faced by international students undertaking flight training which can affect outcomes, in particular, the language barrier that is often present (Baugh & Stolzer, 2018). Factors that may not have been relevant to domestic students, such as language or cultural barriers, may provide insight into this disparity.

From a methodological perspective, this study consisted of univariate analysis. Exploration of additional factors such as grade-point average (GPA), participant age, or specific attributes of mental processing such as perceptual speed may provide more insight as to training performance. Also, whilst a comparatively large sample for this type of study was obtained, it was nonetheless a convenience sample, and this may limit the generalization of research findings to the wider university flight training environment.

Conclusion

The use of simulators to support flight training will continue to be of great importance to the aviation community. A better understanding of the complex relationship between simulator training and pilot proficiency can help to ensure appropriate resource allocation and student support.

Results of this study have reinforced the importance of this relationship consistent with findings from the literature (Taylor et al., 1999, as cited in Martinussen & Hunter, 2017, Vaden et al., 1998, Olson, 2002). Results from RQ1 suggest evidence of a relationship existing between an international student's mean STG and whether they achieved the first solo within the fixed syllabus hours. While the results for RQ2 found a negative correlation between STG and flight time to solo, this finding was insufficient to demonstrate statistical significance. As a result, this study suggests a variety of conceptual and methodological avenues for further research to further clarify this relationship.

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