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The Relationship between Time of Day and Student Check Ride Performance

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The purpose of this research was to investigate if there was a relationship between check ride performance and the time of day that these check rides occur. The population for this study included students in the flight training program at a midsized, midwestern university. The study utilized the results of more than 10,000 check rides, specifically examining the outcome with respect to time of day. A Chi Squared test yielded a significant finding for the data overall (χ^2=363.910, *df*=2, *n*=10998, *p*<.001) indicating that there was a difference in the actual evaluation outcomes when compared to starting time versus the expected outcomes. Further study of chronotypes in aviation and specifically flight training was recommended.

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Fatigue has been a factor in numerous incidents and accidents in aviation including Go! Flight 1002 (National Transportation Safety Board [NTSB], 2009a), Northwest flight 188 (NTSB, 2009b), and Colgan Flight 3407 (NTSB, 2010). In addition, surveys have indicated that as many as 93% of pilots in Europe have had fatigue impact their ability to operate safely (European Cockpit Association, 2012). Roughly 50% have unintentionally fallen asleep while flying, and 25% woke to find their copilot asleep (BBC News, 2013). Members of the British Airline Pilot Association (BALPA) believe that fatigue is a greater threat to airline operations than terrorism (BALPA, 2018). The aviation industry is beginning to recognize the immense threat that fatigue creates in the safe operation of an aircraft. Most of the research on fatigue mitigation has focused on getting enough sleep and enforcing circadian rhythms (Flight and Duty Limitations, 2018), but little focus has been placed on how individuals experience fatigue within a given day.

Each person experiences a day in a different way; we have our chronotype, which is a personal pattern of circadian rhythms that influence our physiology and psychology (Pink, 2018; Randler & Frech, 2006, 2009). Everyone experiences physiological and psychological highs and lows throughout the day, with most individuals experiencing a peak in the morning and a physiological and psychological trough in the midafternoon. Chronobiologists have suggested that generally, people should not attempt to do activities that require focus and attention to detail during these physiological and psychological troughs (Pink, 2018).

The sleep-wake cycle is a major part of a person's chronotype. One's ability to get quality sleep and manage their sleep cycle effectively affects their productivity and performance during a given day and at different times of the day. There have been many studies that have investigated the sleep habits and management of sleep within the collegiate student population (Buboltz, Brown, & Soper, 2001; Hicks & Pellegrini, 1991; Lund, Reider, Whiting, & Prichard, 2010; Pilcher, Ginter, & Sadowsky, 1997; Singleton & Wolfson, 2009; Trockel, Barnes, & Egget, 2000). Additionally, some studies have focused on the relationship between the sleep-wake cycle and academic performance (Borisenkov, Perminova, & Kosova, 2010; Eliasson, Lettieri, & Eliasson, 2010; Medeiros, Mendes, Lima, & Araujo, 2010; Taylor, Clay, Bramoweth, Sethi, & Roane, 2011).

Problem

Since fatigue has been recognized as a threat to the safety of the aviation industry, it behooves aviation educators to help those entering the industry to understand the factors that can influence fatigue, including chronotype. Pilot trainees, or flight students, complete a test at the end of each flight course, referred to as a *check ride*. A check ride can be a three- or four-hour oral [verbal] assessment, and flight evaluation that takes a significant amount of focus and attention. The purpose of this research is to investigate if there is a relationship between check ride performance and the time of day that these check rides occur using extant data. This research could be helpful to improve safety and increase student performance in the flight training environment.

Research Question

The authors sought to answer the following research question:

> What is the relationship between the time of day a student attempts a check ride and the outcome of that check ride?

This question stemmed from the research of Eliasson et al. (2010), Lund et al. (2010), Pink (2018) in evaluation the academic performance of college students by understanding their chronotype as well as the NTSB recognition of fatigue as a major threat to the aviation industry as long ago as 2011 and every year since 2016 (NTSB, n.d.; NTSB, 2019).

Literature Review

College Student Sleep Habits

Lund et al. (2010) investigated the sleep patterns and predictors of disturbed sleep in the college student population. The authors found that from more than 1,000 students surveyed, greater than 60% were categorized as poor sleepers. Students that had trouble sleeping reported more problems with physical and psychological health issues. Many also reported that emotional and academic stress negatively impacted sleep quality.

The findings from Lund et al. (2010) were supported by Buboltz et al. (2017). Their study found that 73% of college students suffer from sleep disturbances. Many of the participants identified that they suffered from some type of anxiety and depression as a result of their sleep difficulties. Like the Lund et al. (2010) study, the Buboltz et al. (2017) study found that many college students sleep in on the weekends and subsequently, perceive less sleep difficulties on the weekend. The findings from these studies are consistent with other studies (Pilcher et al., 1997; Trockel et al., 2000; Hicks et al., 1991; Singleton et al., 2009) regarding the sleep habits of college students.

Relationship between Sleep and Academic Performance

Several studies link both sleep quality and quantity to academic performance. Eliasson et al. (2010) investigated the total sleep duration and the timing of the sleep to the academic performance of college students. Their results indicated that higher performing students had earlier bed and wake times, but did not find as high a correlation between total sleep and higher academic performance. The authors recommended that students attempt to adjust their class schedule to better fit their sleep/wake circadian rhythm. Trockel et al. (2000) found similar results in a study evaluating several variables and their relationship to academic performance. Of all the variables considered, sleep habits were found to have the greatest impact on improved academic performance--specifically earlier bed/wake times.

Another study by Singleton and Wolfson (2009) investigated the effects of alcohol use and sleep on academic performance of college students. While their focus was on the variable of alcohol, they indicated quality of sleep was more of a factor in daytime sleepiness rather than sleep duration. Singleton and Wolfson (2007) indicated that there was a relationship between daytime sleepiness and grades and recommended that more studies need to be done regarding the relationship between sleep habits and academic performance.

Chronotypes of College Students

In its most basic form chronotypes of individuals can be broken down into three categories. An individual is either a *lark*, an *owl*, or what is referred to as a *third bird* or a *hummingbird*. A *lark* typically rises early and feels energized in the morning and throughout the day and fades in the evening. *Owls* tend to wake long after sunrise and peak well into the late afternoon and evening. It is believed that 60-80% of the population falls within the *third bird* category, sometimes referred to as *hummingbirds*, where they are neither larks or owls (Pink, 2018).

An individual's chronotype changes throughout their life. As children, most of us start out as larks. Then, in the early teen years, individuals change to an owl. Next, in early adult hood, sometime after 20 years old, our chronotype changes more towards a lark or third bird (Pink, 2018). The exact point at which our nocturnal preference diminishes is unclear, but it is generally believed that it occurs after college (Hershner & Chervin, 2014).

All chronotypes have a sleep/wake cycle that is different. As mentioned earlier, owls tend to go to bed late and desire to sleep late. They are typically not at their best in the morning. Generally, it is recommended that owls should put off analytical tasks and important decision making to the evening (Pink, 2018). Other researchers have even found that owls are at a distinct disadvantage in the testing process because most testing occurs during a lark's peak hours (Randler & Frech, 2006, 2009). The research indicates that if college students are predominately owls, they should schedule classes, take tests, and study in the evenings and take advantage of the opportunities to learn and take evaluations during their best times.

Methodology

Sample

The population for this study was conceived as all university flight students. A sample was selected that consisted of the students in the flight training program at a midsized, midwestern university, and who underwent check ride events from January 1, 2006 to June 20, 2018. This timeframe was chosen for convenience as this encompasses the period that this particular flight training program has utilized electronic record keeping for flight training events.

Data

The data were requested from the flight training program after receiving approval for the study from the institutional review board. The data were de-identified prior to being delivered to the researchers for analysis. As such, the only data provided by the flight training program were those specifically requested, namely the hour that the evaluation began (hourly from 6am to 8pm), type of evaluation (oral, flight, or simulator), and outcome (satisfactory or unsatisfactory). First attempts only were requested to ensure that the same applicant did not appear in the data for the same event at the same certification level, in hopes of preserving the independence of the data for the Chi Square analysis. The nature of the data provided led to some limitations of the study, namely the inability to correlate any demographic information in the analysis. The data also lacked information about individual participant's aeronautical experience, such as their recorded flight experience, at the time of their check ride. The lack of information regarding total aeronautical experience meant that there was no way to account for this potential confounding variable.

Data Analysis Procedure

The analysis was a compilation of 15 separate Chi Squared analyses, one for each starting time by hour, and a 16^{th} of the overall data. The use of multiple tests led to the decision to adjust the critical *p* value to determine significance using the Bonferroni correction. With 16 tests and a planned significance of $\alpha=.05$, the researchers could determine statistical significance only for *p* values less than .003125. The limited nature of the data protected the identities of the students from the flight training program but prevented any analysis of the demographic information of the sample.

The sample provided was of reasonable size (n=11,011) and only included categorical data. The nature of the data led to the decision to use a contingency table and Chi Squared analysis, using SPSS v. 22.0, to analyze the data. The analysis was run to compare the type of event (oral, flight, or simulator) with the outcome of the event (satisfactory or unsatisfactory) and account for the time of day. This resulted in a three-variable contingency table. In reviewing the data, several outlier data points were found indicating evaluation events that occurred at abnormal times (between 9pm and 5am). When the faculty of the flight training provider were queried, they indicated that these were most likely events that were scheduled at times that would not create resource conflicts within the scheduling system, but the evaluations were likely not conducted at those listed times. The researchers were left with no way to ascertain the time that these evaluations occurred and so these 13 events were eliminated from the data analysis leaving a remaining sample size of n=10998. While the Chi Squared analysis indicated that some of the data were significant, the researchers could not determine what element was significant. To understand the underlying relevance and relationship between the variables, a post-hoc binary logistic regression was conducted.

Results and Discussion

The Chi Squared test yielded a significant finding for the data overall (χ^2=363.910, df=2, n=10998, p<.001), indicating that there is a difference in the actual evaluation outcomes when compared to starting time versus the expected outcomes. Upon closer examination, several starting times were found to have significant impact on outcomes as well, specifically 8am-11am, 1pm, and 3 pm. The data are available for all times in Table 1.

In addition to the significance of the Chi Squared values, a Cramer's V was also calculated to give an idea of the strength of the associations found through the Chi Squared analysis. The values of Cramer's V indicate a weak relationship between time of day and outcome of the evaluation event for all separate times as well as entire dataset when viewed as a whole. The Cramer's V values for all the evaluation times can also be found in Table 1.

Table 1

Statistics for χ^2, degrees of freedom, n, χ^2 significance, and Cramer's V for all evaluation starting times by hour

Time	χ^2	*df*	*n*	χ^2 Significance	Cramer's V
6am			9		
7am	2.361	1	251	0.124	0.097
8am	124.557	2	3029	<.001*	0.203
9am	11.658	1	563	.001*	0.144
10am	31.314	2	1811	<.001*	0.131
11am	9.171	1	241	.002*	0.195
12pm	6.875	2	166	0.032	0.204
1pm	92.772	2	2684	<.001*	0.186
2pm	3.918	1	347	0.048	0.106
3pm	55.93	2	1721	<.001*	0.18
4pm	2.74	1	52	0.098	0.23
5pm	2.296	2	95	0.317	0.155
6pm	0.434	2	15	0.805	0.17
7pm			9		
8pm			5		
Total	363.91	2	10998	<.001	0.182

Note. Blank entries indicate statistics could not be computed because outcome was a constant. * indicates significance at a Bonferroni adjusted level of .003. Cramer's V significance levels identical to χ^2 significance levels.

The significance of the 8am, 10am, 1pm, and 3pm starting times are difficult to gauge because the p value returned simply indicated it was less than .001, but the adjusted residuals of those starting times provided us with an indicator of the strength of the significance. In all cases, the adjusted residuals for opposing outcomes were identical in magnitude but opposite in sign. Positive adjusted residuals indicated that the observed values were greater than expected while negative meant the opposite. The adjusted residual at 8am for satisfactory oral evaluations was 11.1 and for satisfactory flights was -11.2 indicating there were more satisfactory oral evaluations and fewer satisfactory flight evaluations than would be expected by chance. These indicate very significant statistical values at over 11 standard deviations. The adjusted residuals for the remaining three times ranged from -2.3 for satisfactory simulator evaluations at 3pm to 9.6 for satisfactory oral evaluations at 1pm. These adjusted residuals help to explain the differences that were found between the expected and observed outcomes for the type of exam within the same times as well. Statistically significant differences at the .05 level were found between satisfactory and unsatisfactory, for both oral and flight evaluations at 8am, 9am, 10am, 11am, 1pm, and 3pm. These data for the listed times, including adjusted residuals, can be found in Tables 2 and 3. The only time that there was a significant difference between outcomes for simulator evaluation was at 3pm.

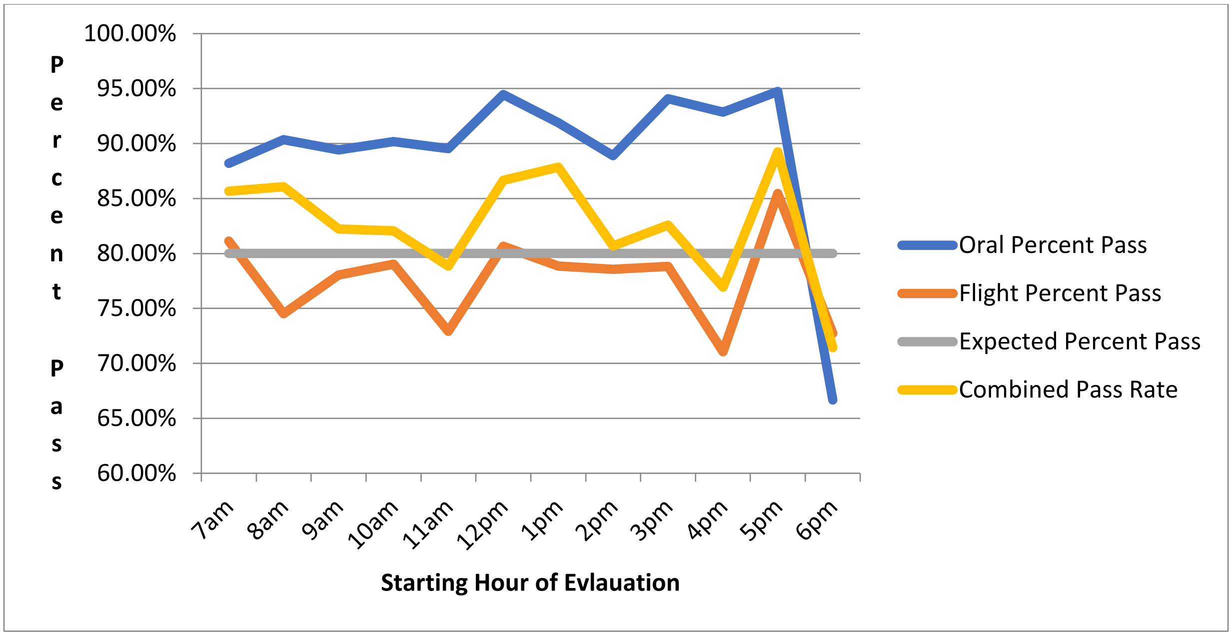

Figure 1. Oral, Flight, and Combined Percent Pass vs. Expected Pass Rate

Figure 1 gives an overview of the overall combined pass rates as well as each individual type; oral and flight. While the oral pass rate remains relatively high throughout the day, the flight pass rate seems to take a dip in the late morning as well as the late afternoon. These dips potentially could be explained by the students' chronotypes. An owl, for example, would expect a dip in focus and energy in the morning and gradually become more alert and focused as the day moves into the evening hours. The third bird that Pink (2018) refers to would be more likely to experience that same trough in focus and energy late in the afternoon.

Table 2

Count and Adjusted Residual Values by time: 8AM to 12PM

timeday				Outcome Satisfactory	Outcome Unsatisfactory	Total
8 AM	typeexam	Oral	Count	1993_a	213_b	2206
			Adj.Residual	11.1	-11.1	
		Flight	Count	608_a	208_b	816
			Adj.Residual	-11.2	11.2	
		Sim	Count	6_a	1_a	7
			Adj.Residual	.0	.0	
	Total		Count	2607	422	3029
9 AM	typeexam	Oral	Count	186_a	22_b	208
			Adj.Residual	3.4	-3.4	
		Flight	Count	277_a	78_b	355
			Adj.Residual	-3.4	3.4	
	Total		Count	463	100	563
10 AM	typeexam	Oral	Count	440_a	48_b	488
			Adj.Residual	5.5	-5.5	
		Flight	Count	1032_a	274_b	1306
			Adj.Residual	-5.2	5.2	
		Sim	Count	12_a	5_a	17
			Adj.Residual	-1.2	1.2	
	Total		Count	1484	327	1811
11 AM	typeexam	Oral	Count	77_a	9_b	86
			Adj.Residual	3.0	-3.0	
		Flight	Count	113_a	42_b	155
			Adj.Residual	-3.0	3.0	
	Total		Count	190	51	241
12 PM	typeexam	Oral	Count	68_a	4_b	72
			Adj.Residual	2.6	-2.6	
		Flight	Count	75_a	18_b	93
			Adj.Residual	-2.6	2.6	
		Sim	Count	1_a	0_a	1
			Adj.Residual	.4	-.4	
	Total		Count	144	22	166

Note. Each subscript letter denotes a subset of outcome categories whose column proportions do not differ significantly from each other at the .05 level.

Table 3

Count and Adjusted Residual Values by time: 1PM to 3PM and Total

timeday				Outcome Satisfactory	Outcome Unsatisfactory	Total
1 PM	typeexam	Oral	Count	1700_a	150_b	1850
			Adj.Residual	9.6	-9.6	
		Flight	Count	652_a	175_b	827
			Adj.Residual	-9.5	9.5	
		Sim	Count	5_a	2_a	7
			Adj.Residual	-1.3	1.3	
	Total		Count	2357	327	2684
2 PM	typeexam	Oral	Count	64_a	8_b	72
			Adj.Residual	2.0	-2.0	
		Flight	Count	216_a	59_b	275
			Adj.Residual	-2.0	2.0	
	Total		Count	280	67	347
3 PM	typeexam	Oral	Count	396_a	25_b	421
			Adj.Residual	7.2	-7.2	
		Flight	Count	1013_a	272_b	1285
			Adj.Residual	-6.7	6.7	
		Sim	Count	9_a	6_b	15
			Adj.Residual	-2.3	2.3	
	Total		Count	1418	303	1721
Total	typeexam	Oral	Count	5132_a	502_b	5634
			Adj.Residual	19.0	-19.0	
		Flight	Count	4149_a	1165_b	5314
			Adj.Residual	-18.7	18.7	
		Sim	Count	36_a	14_b	50
			Adj.Residual	-2.5	2.5	
	Total		Count	9317	1681	10998

Note. Each subscript letter denotes a subset of outcome categories whose column proportions do not differ significantly from each other at the .05 level.

The Chi Squared analysis indicated that the data were significant at numerous times of day but could not reveal what about them was significant. The analysis also did not indicate what elements of the other two independent variables had significant impact on the outcome of the evaluation. To answer those, a binary logistic regression was conducted over all the data using SPSS V. 22.0. The regression model predicted 68% of the outcomes and used a cut value of .800. The cut value of .800 was chosen because the industry standard for check rides is an

80% first time pass rate. The regression model found statistical significance on the outcome for nearly all the times of day except 6am and 7pm, three of the training courses (two commercial experience courses and instrument certification), and oral evaluations. These data are displayed in Tables 4 and 5. It is interesting to note that all the β values for all the significant times were positive indicating that time of day, while statistically significant, may not have a practical significance. The least favorable time to begin an evaluation, according to the regression model, was 5pm. The course that a student is enrolled in has greater impact on the probability of successfully completing their check ride on the first attempt. The proficiency courses in preparation for commercial certification had the highest positive impact on check ride outcome (β= 1.014 for the first commercial experience course and β=1.342 for the second commercial experience course) while the certification courses, especially instrument certification had the greatest detriment (β=-1.101 for the instrument rating certification course). While the effect did not appear to be large, the probability of passing a check ride on the first attempt did vary by up to roughly one percent depending on the course the student is taking. The type of evaluation also impacted the probability of success with an oral evaluation being more likely to succeed (β=.527) while the flight is less so (β=-.638). It is interesting to note that only the flight evaluation was statistically significant (p=.043).

Table 4

Classification Table

			Predicted		
			Outcome		
	Observed		Unsatisfactory	Satisfactory	Percentage Correct
Step 1	outcome	Unsatisfactory	990	691	58.9
		Satisfactory	2832	6485	69.6
	Overall Percentage				68.0

Note. The cut value is .800

Table 5

Variables in the Equation

		β	*SE*	Wald	*df*	Sig.	Exp(β)	95% C.I.for EXP(β)	
								Lower	Upper
Step 1	timeday			40.542	14	.000			
	timeday(1)	20.861	12717.089	.000	1	.999	1148114532.988	.000	.
	timeday(2)	1.793	.409	19.242	1	.000	6.006	2.696	13.379
	timeday(3)	1.683	.362	21.563	1	.000	5.381	2.645	10.949
	timeday(4)	1.747	.378	21.402	1	.000	5.736	2.736	12.021
	timeday(5)	1.835	.364	25.390	1	.000	6.263	3.068	12.786
	timeday(6)	1.562	.399	15.343	1	.000	4.769	2.182	10.419
	timeday(7)	2.036	.427	22.739	1	.000	7.662	3.318	17.694
	timeday(8)	1.868	.364	26.386	1	.000	6.479	3.176	13.216
	timeday(9)	1.735	.388	20.020	1	.000	5.671	2.652	12.129
	timeday(10)	1.875	.366	26.303	1	.000	6.522	3.185	13.353
	timeday(11)	1.473	.507	8.457	1	.004	4.363	1.616	11.774
	timeday(12)	2.415	.492	24.072	1	.000	11.190	4.264	29.364
	timeday(13)	1.591	.695	5.240	1	.022	4.907	1.257	19.154
	timeday(14)	21.265	12763.173	.000	1	.999	1719152707.934	.000	.
	course			301.070	11	.000			
	course(1)	-.260	.241	1.165	1	.280	.771	.480	1.237
	course(2)	.035	.214	.026	1	.871	1.035	.680	1.575
	course(3)	-.384	.207	3.437	1	.064	.681	.454	1.022
	course(4)	1.014	.234	18.763	1	.000	2.756	1.742	4.360
	course(5)	1.342	.246	29.799	1	.000	3.827	2.364	6.197
	course(6)	.065	.211	.094	1	.759	1.067	.706	1.612
	course(7)	-1.101	.236	21.704	1	.000	.332	.209	.528
	course(8)	-.078	.240	.106	1	.745	.925	.578	1.480
	course(9)	.236	.223	1.119	1	.290	1.266	.818	1.958
	course(10)	.399	.237	2.830	1	.092	1.491	.936	2.374
	course(11)	-.149	.243	.374	1	.541	.862	.535	1.388
	typeexam			328.171	2	.000			
	typeexam(1)	.527	.315	2.802	1	.094	1.693	.914	3.137
	typeexam(2)	-.638	.316	4.092	1	.043	.528	.285	.980

Note. Variable(s) entered on step 1: course, typeexam.

Conclusions

This study is a first look into chronotypes in aviation flight training. While the data show a possible relationship between check ride performance and time of check ride, the study ultimately led to more questions than answers about the effect of chronotype on collegiate aviation flight students. While the sample size was large, there are three major limitations of this study: (a) the use of only one school's data, (b) the limited timeslots for check ride starts (with most events beginning between 8 am and 3 pm), and (c) the lack of more detailed demographic and background information on the sample. The lack of demographic and background data makes it impossible to identify individuals' chronotypes or account for potentially confounding variables. Pink (2018) indicated that in the teen years most people transition to being owls and at around twenty years of age, preferences shift to a lark or third bird making it nearly impossible to determine the chronotype of the college age students in this study.

Recommendations

Further study of chronotypes in aviation and specifically flight training should be conducted. Most importantly, identification of participant chronotype in advance of measuring performance would have greatly improved analysis of study results. Future studies should seek a finer analysis of check ride characteristics to determine if chronotypes have more of an effect on oral exams, flight exams, or more complex types of check rides, such as instrument or flight instructor. Additionally, a study at an institution that trains and tests 24 hours a day would be valuable, such as at a simulator training institution. Fatigue has been recognized as a threat to aviation safety, but it seems to be one that can be overcome with proper understanding of what causes fatigue and mitigation techniques. Future research is indicated on the impact of teaching flight students about healthy sleep habits, healthy eating habits, healthy exercise habits, healthy ways to counter sleep debt, and their individual chronotype.

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