Vigilance Aid Use and Aircraft Carrier Landing Performance in Pilots of Tactical Aircraft

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BACKGROUND: Fatigue is a well-known hazard in aviation. In military fighter communities, policies have evolved to allow for in-flight use of pharmacological vigilance aids to counteract the negative effects of fatigue. With limited objective evidence supporting the role of these medications in continuous flight operations, the present study seeks to evaluate whether use of modafinil is associated with pilot aircraft carrier landing performance.

METHODS: A retrospective, observational study was completed following carrier-based flight operations in support of Operation Inherent Resolve. All graded landing passes were included in the analysis. Mixed-effect multivariate linear regression analysis was utilized for the primary outcome of landing signal officer grade of landing performance following combat sorties for events with reported in-flight use of modafinil.

RESULTS: A total of 1122 sorties were flown by 79 different pilots with an average landing pass grade of 3.86. The primary outcome of modafinil use in-flight was not generally associated with landing performance. In a subset analysis of more senior ranked aviators, modafinil use appeared to offer a relative performance improvement back to baseline (+0.19). Secondary outcome analysis revealed landing performance was associated with advanced landing technologies (+0.25), sorties later in deployment (+0.05 per 30 d), total career carrier landings (+0.03 per 100 traps), and longer mission duration (-0.04 per hour).

DISCUSSION: In the context of evidence supporting subjective benefits of vigilance aid use by aircrew, the results of this study provide ample objective support to the controlled use of modafinil in the operational environment.

KEYWORDS: vigilance aids, modafinil, pilot performance, aircraft carrier landing, tactical aircraft.

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Fatigue is a well-known hazard in aviation. Pilots are expected to perform complex tasks with little room for error, often despite long and unpredictable work hours, circadian rhythm disruptions or insufficient sleep. As a result, fatigue continues to pose a significant, ongoing issue for flight operations in both civilian and military communities. In military aviation, a recent survey reported that inconsistent shiftwork, suboptimal sleep quality, and fatigue are common among U.S. Army aviators.[14] A survey of U.S. Air Force pilots and navigators from 2005 found that 94% of respondents reported performance degrading effects of fatigue, with 65% having experienced unintentional sleep while flying.[17]

Military aircrew operate in challenging environments with conditions predisposed to the development of fatigue. In a deployed setting, flight operations often run around-the-clock, increasing aircrew workload and mission planning requirements. Mandatory crew rest regulations have specific scheduling requirements to facilitate sleep, but sleep quantity and quality are frequently reduced, and dynamic shift and alert schedules invariably disrupt natural circadian rhythms.[2,18] Reports of fixed-wing aviators during continuous aircraft carrier operations suggest that aircrew subjectively feel their mission capabilities degrade after multiple consecutive days of flight operations.[22] Such an operational tempo creates a preload for fatigue, diminishing a pilot's physiological reserve prior to flight. When in-flight, mission tasking is unpredictable, characterized by potentially long periods of relatively low workload broken up by quick bursts of task-saturation, highly prone to

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the negative effects of fatigue with often razor-thin margins for error.[12]

Unmitigated, fatigue causes a spectrum of physical and cognitive deficits, which range from sleepiness to micro sleep episodes that may threaten flight safety. Impaired central nervous system functioning, notable for degraded short term memory, increased reaction time, lapses in vigilance, and altered mood are a few of the concerning physiological consequences to the aviator.[3,6] Oculomotor deficits and spontaneous microsleeps are known to occur.[10,23] Specific skills intrinsic to the safety of flight known to deteriorate include radio communications, dexterity and fine motor control of flight control inputs, and execution of flight maneuvers.[7,16] Ongoing study of the effects of fatigue with systems to minimize or eradicate its negative effects is critical to military aviation.

In fighter communities, with few options in-flight to counteract fatigue, policies have evolved to provide for use of pharmacological vigilance aids. Historically, the medication of choice was amphetamine or one of its derivatives. More recent evaluation of modafinil in aviation communities has shifted attention to this medication with theoretically lower addiction potential and improved safety profiles. Controlled simulator studies have demonstrated the efficacy of modafinil at maintaining alertness and performance.[7,8] Ground testing studies have supported the low side effect profile and overall safety of modafinil in aviation communities.[20] Of note, use of vigilance aids when fatigued may not adversely impact acceleration or G tolerance, an important consideration in fighter communities.[21]

Objective data supporting the effectiveness of vigilance aid medications in the operational environment are limited, but a growing body of evidence derived from surveys and other subjectively reported outcomes underscores the potential value such vigilance aids can offer. After Operations Desert Shield and Storm, a retrospective survey of tactical squadrons revealed a high utilization of amphetamines, which were reported as beneficial or essential to operations.[11] In a survey of deployed F-16 fighter pilots, dextroamphetamine was perceived as being highly effective at managing fatigue.[18] A study of F-15E aircrew with pre- and postflight Stanford sleepiness scale (SSS) scores showed use of dextroamphetamine or modafinil was associated with reduction of in-flight and postflight fatigue without significant differences in undesirable or adverse postflight physiological symptoms.[12]

In aggregate, these studies provide invaluable insight into the subjectively reported benefits of in-flight vigilance aid use, but draw attention to the need for objective evidence regarding the real-world effects of their use on pilot performance in deployed or operational settings. The present study seeks to fill this gap in knowledge by evaluating whether in-flight fatigue management with use of the pharmacological alertness aid modafinil during continuous combat flight operations has any association with aircraft carrier landing performance. Aircraft carrier landing performance is an ideal candidate for analysis because it is an objective metric of pilot performance during a critical phase of flight which is highly susceptible to the cumulative adverse effects of fatigue following long combat sorties.[19] Every landing pass aboard an aircraft carrier is subjected to scrutiny and graded on a defined scale. In this retrospective analysis of combat sorties during Operation Inherent Resolve, the landing performance of pilots who utilized modafinil in-flight is compared to those without in-flight use.

METHODS

The present study is an observational, retrospective analysis of flight records following completion of combat flight operations in support of Operation Inherent Resolve during a deployment aboard a United States Navy aircraft carrier. The study was determined to be exempt by the Institutional Review Board at Naval Medical Center San Diego. Landing signal officer (LSO) grades of landing performance following combat sorties with reported in-flight use of modafinil are compared to sorties without use.

Subjects

The primary outcome of the study is the LSO grade of landing performance aboard the aircraft carrier. Every landing pass aboard a U.S. Navy aircraft carrier is tightly controlled by the LSO team, which is tasked with oversight of this exceptionally hazardous phase of flight. The LSO team is composed of airwing pilots trained specifically on safe approaches and landings aboard the aircraft carrier. The LSO provides direct voice communications and visual signals to the pilot during every landing approach. After completion of the landing cycle, the LSO team assigns grades for every successful landing and landing pass attempt on a zero- to five-point scale as follows:

0 = Unsafe landing. The pilot successfully lands onboard the aircraft carrier, but puts the aircraft or aircraft carrier at unnecessary risk.

1 = Wave-off. The pilot is operating outside of controlled parameters on approach, such that a safe landing is in doubt. No landing is permitted and the pilot is required to make another approach.

2 = Wave-off for pattern. The pilot is flying outside of proper parameters for the landing pattern to allow for a safe approach, and is required to abort the approach.

2.5 = Bolter. The aircraft touches down on the aircraft carrier deck, but does not engage an arresting wire, resulting in an unsuccessful landing attempt.

3 = Fair pass. The pilot makes a safe landing aboard the aircraft carrier but the approach was less than ideal.

4 = Good pass. The pilot makes a safe landing aboard the aircraft carrier and the approach was within parameters.

5 = Excellent pass. Rarely given, the pilot makes a safe landing aboard the aircraft carrier without any deviations.

This standard scale is used by the LSO to grade every carrier landing pass and is used for the calculation of landing grade-point-averages (GPA). For reference, the minimum requirement for initial carrier qualification is a landing pass GPA of 2.5

with a boarding rate of 60%. The landing pass grade is continuously monitored by the airwing commander as a measure of pilot performance to identify potential safety or performance issues. The LSO may determine certain landing passes to be exempt from being graded due to circumstances beyond the pilot's control, such as foul or unsafe conditions on the flight deck requiring wave-off (aborted landing pass) or aircraft systems malfunctions which unduly impede pilot performance.

Procedures

Oversight and regulation of in-flight use of modafinil is described in the U.S. Navy's "Performance Maintenance During Continuous Flight Operations" program, as described in NAVMED P-6410.[1] Subject to the approval and oversight of the airwing commander and flight surgeon, airwing pilots were voluntarily eligible to participate in the "Performance Maintenance During Continuous Flight Operations" program, which allowed for controlled use of the vigilance aid modafinil to counteract in-flight symptoms of fatigue. Participation was restricted to aircrew of the Boeing F/A-18C/E/F Hornet/Super Hornet and EA-18G Growler. Prior to enrollment, all participants were screened by their flight surgeon for potential contraindications to vigilance aid use. All participants were counseled regarding nonpharmacological preflight fatigue countermeasures and lifestyle changes, including crew rest, circadian rhythm management, sleep hygiene, exercise, diet, and hydration. Participants were required to ground test a single dose of 200 mg modafinil prior to use in-flight to experience the vigilance aid effects and document any potential undesirable or adverse effects.

If ground testing was determined by the pilot and flight surgeon to be safe, aircrew were medically authorized for limited, elective use of modafinil in-flight to counteract symptoms of fatigue or reduced alertness. Pilots were instructed they may take one dose of 200 mg modafinil for symptoms of fatigue, and may repeat a single dose within 30 min if alertness was not reestablished, for a maximum cumulative dose of 400 mg modafinil. Limited doses of 200 mg of modafinil were distributed to each aviator. Use of modafinil in-flight was entirely voluntary and no routine use was authorized. Modafinil was only permitted for use during combat sorties, excluding training or routine flight events. All participating aviators were required to document all in-flight use of modafinil, with instruction to report any potentially concerning or undesirable effects of medication use to their flight surgeon.

Statistical Analysis

All graded landing passes of combat sorties in support of Operation Inherent Resolve are included for analysis. Landing passes which received no grade are excluded. Descriptive statistics are reported for all landing passes and use of modafinil. The GPA of combat flights with reported in-flight use of modafinil is compared to the GPA of combat flights without use of modafinil using mixed effects linear regression analysis to account for intrapilot covariance of landing performance. Multivariate mixed effects linear regression analysis is carried out for secondary outcomes associated with landing performance and modafinil use. Pearson Chi-squared and Wilcoxon rank sum are used to compare independent categorical variables and nonparametric means between flights with and without reported modafinil use. Unadjusted and adjusted results of analysis are reported.

Secondary outcomes of the study likely to be associated with landing performance include pilot rank, pilot total career landings or 'traps', aircraft series, mission duration, day/night landing pass, and time during deployment of the flight event. Pilot rank and total career landings or 'traps' are indicative of pilot experience and likely to influence individual landing performance. Aircraft series is likely to be associated with landing performance as the older model F/A-18C "Legacy" Hornet is not equipped with the more advanced landing assist technologies. The more recent models of the F/A-18 (F/A-18E/F and EA-18G) are equipped with technology referred to as Maritime Augmented Guidance with Integrated Controls for Carrier Approach and Recovery Precision Enabling Technologies, also known as MAGIC CARPET or precision landing mode (PLM), developed with the intent of improving boarding rates and landing performance. Longer missions are more susceptible to performance degrading fatigue. Night landing passes are considered more challenging than day landing passes and often take place during circadian troughs which may negatively influence performance.[5] Lastly, time during deployment is included in analysis as it may independently influence landing performance, either positively as a result of practice or experience gained over the deployment, or negatively with the cumulative stress of a demanding operational tempo. Alpha level was set at 0.05. Statistical analysis was completed with STATA 12 and Microsoft Excel.

RESULTS

A total of 1122 Operation Inherent Resolve combat sorties flown by 79 different airwing pilots during a recent deployment aboard a U.S. Navy aircraft carrier were identified for analysis. There were no adverse or undesirable side effects of modafinil use in-flight reported. No aviator who successfully completed ground testing was later determined to be medically disqualified or otherwise ineligible for continued voluntary participation in the "Performance Maintenance During Continuous Flight Operations" program.

Among the group of 79 airwing pilots, 18 (23%) operated the F/A-18C, 34 (43%) operated the F/A-18E, 19 (24%) operated the F/A-18F, and 8 (10%) operated the EA-18G. The 1122 combat sorties resulted in a cumulative total of 1209 landing passes. Of these landing passes 55 (5%) were not graded and excluded, yielding 1154 graded landing passes for analysis. Of the graded landing passes included in analysis, 177 (15%) were flown by pilots of the F/A-18C, 510 (44%) by pilots of the F/A-18E, 306 (27%) by pilots of the F/A-18F, and 161 (14%) by pilots of the EA-18G. The average mission duration was 7.24 h [interquartile range (IQR) 7.3–7.6 h]. Overall landing performance was good, as 1023 passes (89%) received the grade of good pass (landing grade = 4) or better, 96 (8%) received the grade of fair pass (landing grade = 3), and the remaining 39 (3%) received lower grades (**Fig. 1**).

Modafinil was utilized in-flight for any combat sortie by 57 of the 79 study pilots (72%). Of the 1154 graded passes, 386 (33%) had reported in-flight use of modafinil. Analysis of modafinil use in-flight revealed several trends of interest. (**Fig. 2**). Pilots who elected to use modafinil tended to be more junior in rank, with use rate of 37% among pilots of rank O3 [Lieutenant (USN) or Captain (USMC), Pearson Chi-squared $P < 0.01$] who had comparably fewer total career landings (258, IQR 145–350, Wilcoxon Rank Sum $P < 0.01$) (**Table I**). Furthermore, pilots of the F/A-18C (single seat "Legacy" Hornet) had slightly higher use rates (43%) while pilots of the F/A-18F (tandem-seat Super Hornet) had slightly lower use rates (21%, Pearson Chi-squared $P = 0.02$). Modafinil usage tended to increase later in deployment, from an average of 29% of OIR events during the first 30 d to 36% during the final 30 d (Pearson Chi-squared $P = 0.03$).

The overall unadjusted grade point average for all landing passes was 3.86 [95% confidence interval (CI): 3.84–3.89]. The unadjusted GPA for passes without associated modafinil use was 3.86 (95% CI: 3.83–3.89). For passes associated with in-flight use of modafinil, the unadjusted GPA was 3.87 (95% CI: 3.82–3.91). Multivariate analysis revealed no significant association between landing performance and in-flight use of modafinil (**Table II**).

Several secondary outcomes were found to have an association with landing pass GPA (**Fig. 3**). Mission duration in hours was found to have a small negative correlation with landing grade, with every increasing flight hour associated with a reduction in landing GPA by 0.04 (95% CI: -0.07 to -0.01, $P = 0.02$). Aircraft series was associated with landing GPA, with newer F/A-18E/F and EA-18G models collectively having an improved landing GPA compared to legacy F/A-18C with a difference of 0.25 (95% CI: 0.12–0.38, $P < 0.01$). Total career aircraft carrier landings (referred to as traps) had a positive correlation with GPA: for every 100 increase in career traps, an increase in GPA of 0.03 was observed (95% CI: 0.01–0.06, $P = 0.02$). As

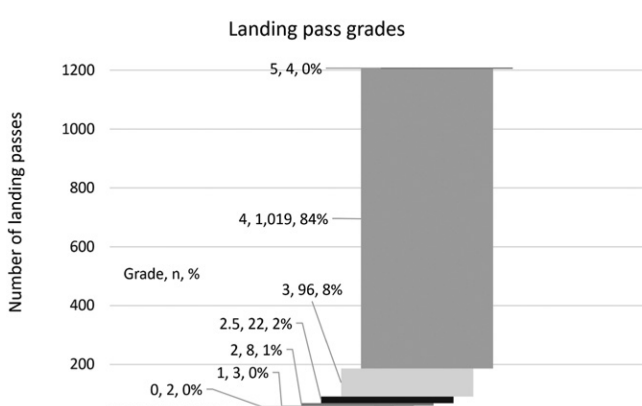

Fig. 1. Distribution of landing grades, reported as landing grade; n; percent of total.

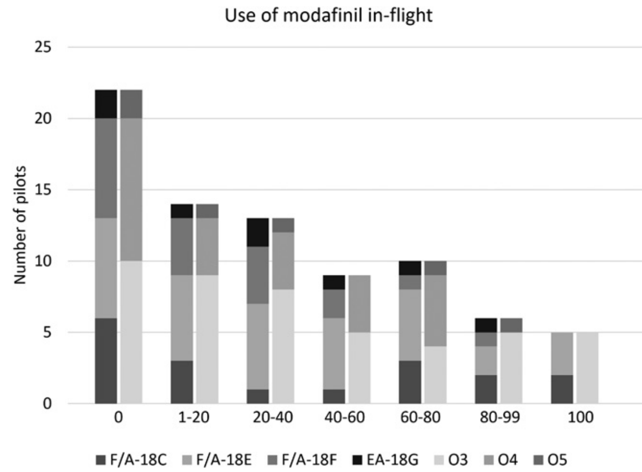

Fig. 2. Frequency of use of modafinil in-flight by aircraft type and pilot rank, with results reported as percentage of sorties with associated vigilance aid use.

deployment progressed, landing grades had mild incremental improvements on average, 0.05 per 30 d ($P = 0.02$). Pilot rank had no association with landing performance. Night landing passes were similarly not associated with a reduced landing GPA.

Subset analysis by aircraft type revealed no association of modafinil use with landing performance. Specifically, there was no association of modafinil use with landing performance in F/A-18C aircraft without equipped PLM technology (95% CI: -0.19–0.19, $P = 0.97$). This trend was similar for analysis of other aircraft. In the case of subset analysis by rank, modafinil use had no association with landing performance for pilots of rank O3 or O4, but for pilots of rank O5 in-flight modafinil use appeared to offer a modest improvement in landing grade. In subset analysis of 108 graded landing passes performed by pilots of rank O5, the unadjusted average GPA was 3.89 (95% CI 3.81–3.96). In-flight use of modafinil was associated with improved landing performance by +0.19 (95% CI 0.03–0.34, $P = 0.02$). No trend existed on subset analysis of total career landing passes.

DISCUSSION

In this study of aircraft carrier landing performance during continuous flight operations, the primary outcome of landing performance was, with one notable exception, not associated with in-flight use of modafinil. Overall landing performance was excellent in this study group, with relatively small variance in landing grades. With no reported safety concerns related to in-flight use, fatigued pilots who voluntarily opted to use the vigilance aid modafinil during long combat sorties generally performed at least as well pilots who did not.

Subset analysis restricted to more senior aviators of rank O5 revealed that in-flight modafinil use may augment landing performance. This select group, composed of more experienced pilots who have many additional duties and stressors above and beyond mission planning or execution, may be at relatively

Table I. Descriptive Statistics of 1154 Landing Passes With and Without Reported Modafinil Use.

	NO USE	MODAFINIL USE	P
Duration (hours, IQR)	7.3, 7.3 - 7.6	7.3, 7.3 - 7.6	0.92*
Day / Night landing (% passes)	67 / 33	66 / 34	0.67**
Aircraft (no. pilots, % passes): F/A-18C	18, 57%	43%	<0.01**
F/A-18E	34, 64%	36%	
F/A-18F	19, 79%	21%	
EA-18G	8, 61%	39%	
Rank (no. pilots, % passes): O3	46, 63%	37%	0.02**
O4	27, 72%	28%	
O5	6, 68%	32%	
Career traps (total, IQR)	282, 150 - 400	258, 145 - 350	0.01*
Time during deployment (day, IQR)	37, 22 - 73	52, 28 - 76	<0.01*

Rank is reported by the following: O3 - Lieutenant (U.S. Navy) and Captain (U.S. Marine Corps); O4 - Lieutenant Commander and Major; O5 - Commander and Lieutenant Colonel.
* Statistical comparison completed with Wilcoxon Rank Sum test; ** Pearson's Chi-squared.

higher risk to experience degrading effects of fatigue during continuous flight operations. Modafinil, then, may be providing these aviators a relative improvement back to their baseline. This particular finding suggests an almost indispensable role for the use of pharmacological vigilance aids, but given the relatively small sample size it should be interpreted with constraint.

There have been numerous studies and surveys of pilots which have previously delineated the subjectively reported benefit of in-flight pharmacological fatigue countermeasures during combat flight operations.[11,15,18] When the broader objective findings of this study are viewed in this context, there is, at the very least, ample evidence that fatigued pilots who opt to make use of pharmacological vigilance aids should safely be able to perform as well as their counterparts at a very complex and hazardous in-flight task. The generally good performance and low variance of landing grades observed in this study may reflect that aircraft carrier landing skills are resilient to the negative effects of fatigue, a finding which has been previously suggested.[4] The high level of attentiveness required for a relatively brief period of time may make performance of this complex task less susceptible to degradation.

Analysis of trends of modafinil use revealed a few interesting results. For a variety of reasons, certain groups may elect for more frequent use of vigilance aids. Modafinil tended to be utilized more frequently by pilots of slightly more junior rank with fewer career landings or 'traps'. These two characteristics, reflective of individual pilot experience, suggest that less experience may contribute to higher stress or cognitive fatigue during continuous flight operations, with the result of more junior aviators experiencing or perceiving more prominent degrading effects of fatigue in-flight. Modafinil use may then be providing some degree of security to these aviators, allowing for safe and effective mission execution. Unlike their more senior counterparts, there was no association of modafinil use with landing performance in junior officers. Whereas the more junior aviator would be more likely to reach for the vigilance aid, it follows that the more senior aviator may benefit most from its use.

The study also revealed a trend toward higher use rates in the single seat F/A-18C with comparably lower use rates in the tandem seat F/A-18F. Higher use rates in pilots of the single seat F/A-18C could plausibly be attributed to the fact that their aircraft were not equipped with the latest landing assist technologies. This feature, or lack thereof, necessitates relatively more manual flight control inputs and cognitive workload during landing – skills which are prone to fatigue. As a result, pilots of the F/A-18C may have been more likely to rely upon vigilance aid use as a means of skills maintenance. For alternative reasons, pilots of the F/A-18F may less frequently opt for use of modafinil given the additional assistance offered by their back-seater/weapon systems officer. This same trend did not appear to apply to pilots of the tandem seat EA-18G Growler, however, suggesting frequency of use of vigilance aids is not strictly a function of the presence of a back-seater. Overall, these observations, while interesting, are felt to have no practical relevance in relation to the primary outcome of this study. The voluntary nature of individual participation in the vigilance aid program

Table II. Results of Mixed-Effect Multivariate Linear Regression Analysis to Control for Intra-Pilot Covariance of Landing Grades.

VARIABLE	LANDING PASS GPA		
	VALUE	95% CI	P
Landing pass GPA	3.86	3.83–3.89	<0.01
Modafinil use	0.002	(-0.07)–0.08	0.96
Mission hours	-0.04	(-0.07)–(-0.01)	0.02
Night landing	0.06	(-0.02)–0.14	0.16
Precision landing mode	0.25	0.12–0.38	<0.01
Rank	-0.05	(-0.16)–0.06	0.38
Career traps (per 100 traps)	0.03	0.01–0.06	0.02
Deployment progress (per 30 d)	0.05	0.01–0.09	0.02

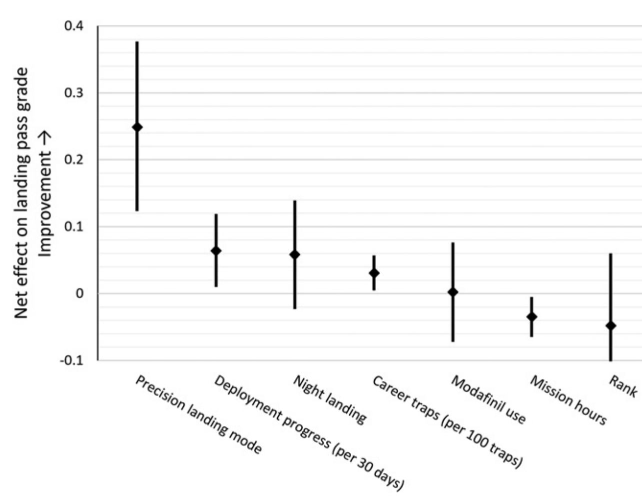

Fig. 3. Adjusted results of mixed effect multivariate linear regression analysis, plotted as net variance of landing pass grade with error bars reflecting 95% confidence interval. Unadjusted average landing pass grade was 3.86 (95% CI: 3.83–3.89, $P < 0.01$).

is likely influenced by many things beyond aircraft configuration, such as squadron culture or other social factors, which are outside of the scope of this study.

The study identified several secondary outcomes of interest to military aviation communities. Increasing mission duration had a small but negative association with landing GPA, suggesting that fatigue was present and having undesirable effects. Pilot experience, as determined by total aircraft carrier career landings, was, unsurprisingly, associated with a relatively small but statistically significant improvement in landing performance. In a related fashion, as deployment progressed, landing grades tended to improve over time, suggesting that experience and practice gained over the course of deployment leads to better performance, potentially offsetting the cumulative fatigue incurred by continuous flight operations, a finding in agreement with previous studies of carrier landing performance.[22]

In this study, PLM-equipped aircraft tended to have higher landing grades compared to older models. Notably excluding the F/A-18C, the presence of Maritime Augmented Guidance with Integrated Controls for Carrier Approach and Recovery Precision Enabling Technologies (MAGIC CARPET), also known as PLM, onboard the more recent models of the F/A-18 (F/A-18E/F and EA-18G) appeared to have the greatest effect on landing performance, more than any of the other human factors studied. This technology aids landing aboard an aircraft carrier by reducing pilot workload and flight control inputs and is widely considered by fleet aviators and LSOs alike to be a valuable feature. The demonstrably superior performance of PLM equipped aircraft observed in this study is a prominent finding, suggesting that iterative advancements in cockpit avionics and automation continue to play a leading role in the safety of military flight operations.

Justifiably held in great favor, the downstream effects of increased cockpit automation should not be overlooked, as increased automation of flight may come at the cost of decreased manual flying skills. Recent studies of airline pilots have found that manual skills are subject to erosion if neglected, with recent flight practice a strong predictor for fine-motor flying performance.[13] Furthermore, cognitive skills associated with manual flight, such as navigation with instrument systems failures, may be prone to deterioration as increased automation comes at the expense of decreased pilot engagement.[9] Fatigue would only exacerbate this relationship of man and machine, and continuous oversight is needed going forward to remain cognizant of human factors in an increasingly automated world.

While this study represents a novel evaluation of pilot performance and modafinil use in combat operations, it has notable shortcomings. The present study was observational and retrospective in nature. Pilot fatigue and use of modafinil were not controlled or randomized. Data variance in landing grades were relatively low with generally good landing performance of the airwing. Additionally, the present study was unable to delineate the interaction between pilot and aircraft with landing performance, as each pilot operated only one aircraft type. Despite these shortcomings, sufficient landing passes were captured that allowed for identification of interesting and relevant trends. As there would be significant safety concerns and operational considerations in the development of a randomized trial for use of pharmacological vigilance aids in theater, retrospective analysis is the most practical and readily available approach. Future widespread data capture in operational settings might reveal new trends of interest and direct further efforts to improve military aviation.

In this study of aircraft carrier landing performance during continuous flight operations, pilots who voluntarily opted to use modafinil to counteract fatigue during long sorties effectively performed the same as pilots who did not. Select groups of aviators may even benefit from vigilance aid use, with a relative trend of improvement back to baseline with use. The study also found that flight duration and pilot experience influenced landing grade, although advancements in landing assist technologies seemed to have a much greater impact on performance. Viewed in the context of the current body of literature documenting the subjective benefits of pharmacological vigilance aids, the findings of this study provide ample objective support of their use during continuous flight operations. As mission profiles and technologies of tactical aircraft continue to evolve to meet the future demands of combat operations, it is imperative to remain vigilant of the man inside the machine.

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