

Integrating Cognitive and Skills Training in a Simulated UAS (Unmanned Aerial Systems) Pilot Training Course

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ABSTRACT

There is a notable absence of set parameters and metrics for training unmanned aircraft system (UAS) pilots and determining piloting proficiency. Outside of safety requirements, individual agencies and organizations use widely varying methods for training and assessment, leading to the critical issue of minimal cohesiveness regarding the expectations of trained pilots. Among the most significant differences between training programs is the role of simulation systems within the training process, with differing opinions regarding how well skills learned in simulators translate to the field. Furthermore, it is valuable to recognize the importance of cognitive skills in UAS piloting. The goal of this pilot study is to begin addressing gaps in existing measures of pilot proficiency by proposing an adapted field instrument that incorporates cognitive skills training and can be effectively transitioned from simulation training to field training. The present work approaches these goals by adapting a preexisting field instrument developed by the National Institute of Standards and Technology (NIST). This adaptation enhanced the existing instrument by incorporating working memory and episodic memory tasks to integrate cognitive training into technical proficiency training. The training course was then integrated into a Mixed Reality (MR) flight simulator designed for small UAS (sUAS) and used in preliminary research. The use of a simulator afforded the flexibility to fine tune the course requirements by adjusting elements to increase difficulty as the research evolved. Changes included more complex targets and requirements of the course. This work demonstrates the potential benefit of an instrument that engages the cognitive mechanisms required of UAS pilots, while prioritizing a practical and efficient training model that addresses the need for instruments that can transition between simulation and field-based training. Doing so bridges existing gaps in comprehensive training, ensuring pilots are equipped to effectively navigate the challenges of their roles.

ABOUT THE AUTHORS

Madison Clausen has a master's degree in clinical psychology from Texas A&M University-Corpus Christi. Ms. Clausen worked with Lone Star UAS Center of Excellence and Innovation for over two years assisting with research examining cognitive factors that impact performance of UAS pilots, with the intention of gaining insight into factors that might impact training and assessment of pilots. Specifically, her work has examined the role of working memory, the impact of increasing mental workload, and the effects of divided attention.

Bailey Miller is a graduate student in Texas A&M University-Corpus Christi's Clinical Psychology Master's program. Mr. Miller works with Lone Star UAS Center of Excellence and Innovation assisting with research that will gain valuable insights into the factors that could impact pilot training and assessment. Currently, his work involves exploring the effectiveness of different cognitive training tasks in enhancing pilot performance during simulations.

Eric T Bird is the Chief Engineer at Lone Star UAS Center of Excellence. For the past six years, he has worked as the Lone Star UAS technical expert and is responsible for the Center's Federal Aviation Administration-mandated mission to safely integrate Unmanned Aerial Systems into the National Airspace System. Prior to working at Lone Star UAS, Mr. Bird was a Principal Simulation Engineer at Bell Helicopter with 17 years of experience in helicopter modeling and simulation. At Bell, Mr. Bird was responsible for the development and release of the V-22 simulation

math model as well as being the Simulation Modeling Lead for the 525 program, helping with development from concept to flight test. Mr. Bird has a Bachelor's Degree in Aerospace Engineering from Texas A&M University and will complete his Master's Degree in Unmanned Systems from Embry-Riddle Aeronautical University in May 2024.

Tye Payne is the Assistant Director of Operations, Testing, & Evaluation at the Lone Star UAS Center of Excellence. Mr. Payne has worked for the last eight years at the LSUASC where he started as a Junior Pilot and has held multiple roles including Range Manager, Project Manager, and Operations Director. Mr. Payne has served as Test Director on projects supporting the FAA, NASA, and a multitude of commercial and public partners. These projects have included collaborations on UAS Traffic Management (UTM), Urban Air Mobility (UAM), and Advanced Air Mobility (AAM). While continuing the advancement of research in UAS operations, Tye has also worked with many public agency partners to develop approaches to the use of UAS for disaster response and emergency management. Mr. Payne is a Veteran of the War on Terror with two tours to Iraq. His background includes a Bachelor's Degree in Project & Technical Management and a Master's Degree in Homeland Security & Emergency Management from Arizona State University.

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INTRODUCTION

Unmanned aircraft systems (UAS) have become increasingly prevalent in recent years. The Federal Aviation Administration (FAA) currently reports over 781,000 registered UAS (FAA, 2024). Over 375,000 of those are commercial aircraft, while the other 400,000 are registered as recreational. Current uses of UAS are broad, including commercial use, emergency response, and military operations, with approximately one out of every three aircraft used by the United States (US) military classified as a UAS (Barnhart et al., 2021; Qi et al., 2018).

Human operators play a critical role in the successful operations of unmanned aircraft (Lercel & Andrews, 2021). Many of the demands required of UAS pilots are similar to that of a manned aircraft, but some present challenges unique to unmanned operations. Some of these unique challenges include a narrowed field of view, a lack of certain sensory information available to manned aircraft pilots, and operation of an aircraft beyond visual line of sight (BVLOS) (Qi et al., 2018). These components can significantly impact pilots' situational awareness and ability to quickly obtain and process information and make efficient and informed decisions with that information. Due to these unique demands, comprehensive training programs specific to UAS pilots are essential in capturing crucial elements of pilot competency. Understanding specific issues in training, the role of simulation, and the role of mental workload is essential to directing the future of UAS pilot training. Using a training module that encapsulates the more complex and unique components of UAS piloting can lead to increased effectiveness and consistency in training.

ISSUES IN UAS PILOT TRAINING

A small UAS (sUAS) is classified by the FAA as a UAS weighing under 55 pounds on takeoff (Small Unmanned Aircraft Systems, 2018). Due to the comparatively limited risk of sUAS operations, licensure requirements are less stringent (Szabolcsi, 2016). Additionally, these regulations only require general requirements of professional UAS pilots and are predominately centered around safety (Dees & Burgett, 2022; Small Unmanned Aircraft Systems, 2018). While safety should be the first step in ensuring pilot competency, it merely scratches the surface of the skills needed to become effective pilots (Wallace, 2016). UAS pilot licensure requirements also pose the challenge of any developing industry in that they are ever evolving, leading to the absence of a clear and established path for new pilots seeking training and licensure (Herrington et al., 2021).

Issues in successful and safe UAS operations have been continually discussed over the last decade. Government agencies, such as the Government Accountability Office (GAO) and Senate Armed Services Committee, have raised concerns regarding the need for more thorough and standardized training (Insinna, 2015; McBride, 2017). The lack of standardization for UAS pilot training may be partially due to the decreased perception of risk. However, despite UAS crashes posing less severe consequences, the overall perception of limited risk in unmanned operations may be misguided. In fact, the GAO reported that a 2015 review found that UAS units experienced more mishaps than any other aircraft units in the US Army (McBride, 2017).

Due to the lack of standardized training protocols, there is a notable lack of consistency in the methodology for training new UAS pilots, and they are often trained through individual programs at the discretion of the organizations for whom they work (Szabolcsi, 2016). Even within stringent training systems, training curriculums and policies for UAS pilots vary. For example, each of the four branches of the US military have different training protocols (Insinna, 2015). Inconsistencies in training may be particularly concerning in scenarios involving collaborative efforts between organizations and agencies where wide variation in training might inhibit pilots' ability to effectively communicate and operate with pilots outside of their organization. For example, a case study of UAV usage in operations responding to hurricanes Harvey and Irma (Greenwood et al., 2020) revealed that the absence of standardization in training contributed to a lack of effective coordination between individuals and organizations conducting UAS operations. Considering their broad usage and the critical missions involving UAS, inadequate and inconsistent training poses greater risk than is often perceived.

The Role of Simulation

The role of virtual flight simulators has been a significant topic of interest surrounding the training of UAS pilots (Parsons, 2013). On one hand, in-field training increases the cost and personnel needs for training (Qi et al., 2018). Field training also risks untrained pilots crashing and causing costly damage to expensive aircraft (Qi et al., 2018). However, while real-world scenarios can be embedded into simulators, there has been concern that training within a simulation may not seamlessly transition into piloting real missions (Parsons, 2013). Considering these concerns, there is cause for an instrument that can be used in a flight simulator and then transferred into field training once the pilot has reached adequate proficiency.

Despite concerns, the advantages of using flight simulators in training have made their usage a primary method for training (Williges et al., 2001; Myers et al., 2018). Reducing safety concerns is a primary benefit of simulator-based training. They also provide the opportunity to practice procedures for situations that may not be feasible to practice in the field. For example, an engine failure is an obstacle that is likely to be encountered in the field but cannot easily, or safely, be replicated in field training. Reduction of costs, conservation of resources, and ease of use may also be a benefit. Where a live aircraft may encounter technical issues that might halt, or delay training, simulators can provide continuous training and repetition of target skills.

Standard Test Methods

Despite the need for comprehensive training, there were no uniform instruments for training and assessment of unmanned aircraft pilots until 2020, when the National Institute of Standards and Technology (NIST) launched their standard test methods for sUAS. This training instrument was designed to provide guidance and structure for organizations utilizing UAS, particularly those who train new pilots. The instrument boasts the benefit of using a tiered system, which begins with basic proficiency in open lanes and then progresses to obstructed lanes and increasingly difficult target acquisition. The NIST course addresses the need for technical proficiency in operating the aircraft. However, it does not address some of the complex components of UAS piloting, such as mission logistics and managing mental workload.

The Cognitive Demands of UAS pilots

Analysis of the cognitive requirements involved in remotely piloting an aircraft has shown that cognitive demand is a critical component to successfully operating a UAS. As UAS technology advances and UAS platforms are used in increasingly complex operations, the mental workload required of pilots increases (Qi et al., 2018). Components such as a pilot's narrowed attentional focus, increase in heart rate (suggesting higher stress levels), and subjective report of heightened mental workload have been positively correlated with a risk of crashing (Qi et al., 2018). Other cognitive factors that may impact pilot proficiency include visual and auditory perception, situational awareness, decision-making, attention, and attitude.

Attention is of particularly high interest in relation to piloting, as monitoring and operating an aircraft requires an advanced ability to distribute one's attention effectively and efficiently (Lercel & Andrews, 2021). The ability to efficiently distribute attention is supported by increased familiarity with concepts and tasks, as well as an ability to quickly process information. Distributing attention also relates to employing short- and long-term memory, which are of the most relevant cognitive processes relating to piloting (Lercel & Andrews, 2021). Pilots must continuously take

in, process, and utilize information to produce verbal responses or act in a way that supports mission completion. Short-term, or working, memory is a key component to this process. Adequate long-term memory capabilities are essential to remembering mission objectives and recalling the important concepts and skills necessary to operate productively.

Precise and prompt decision-making is necessary for successfully conducting UAS operations. In many cases, the perception of limited risk may lead to less caution among new pilots and a lower tendency toward careful decision-making (Herrington et al., 2021). However, minimal training may also lead to apprehensiveness in making decisions and compromise effective problem-solving (Wheatcroft et al., 2017). A study by Wheatcroft et al. (2017) found professionally trained pilots to show higher confidence and better outcomes in decision-making tasks during a simulated flight than private pilots. Video game players also seem to perform better in simulated flights focused on decision-making (Wheatcroft et al., 2017; Ferraro et al., 2022). This may suggest that training related to risk assessment and problem-solving via experiential learning, in general, may have positive effects on abilities in these domains. Despite this potentially positive transfer of skills, however, those with professional pilot training still seem to outperform video game players in flight assessments (McKinley & McIntire, 2009).

Previous research investigating mental workload (Scarince et al., 2022) has been conducted with the NIST (2020). This study took place as a field study with the physical course and aimed to measure auditory and visual working memory by requiring participants to complete concurrent cognitive tasks during flight. For auditory working memory, participants were read a series of up to nine numbers and asked to orate them back verbatim. To test visual working memory, they were asked to look at presented stimuli outside of the flight path to complete a change detection task involving up to eight colored squares. Each participant completed one flight without any external task, one with the visual working memory task, and one with the auditory working memory task. They also independently completed both working memory tasks. Results indicated performance in all three domains was negatively impacted in the dual task conditions, demonstrating the effects of increasing mental workload and dividing attention on task proficiency. This work also demonstrated the impact of working memory on flying and flying on working memory. However, the visual working memory task required the pilots to momentarily take their attention away from the flight task completely. Isolating and independently observing working memory as the primary cognitive mechanism may require embedding the tasks into the course.

CURRENT STUDY: EXPERIMENT ONE

Procedures and Apparatus

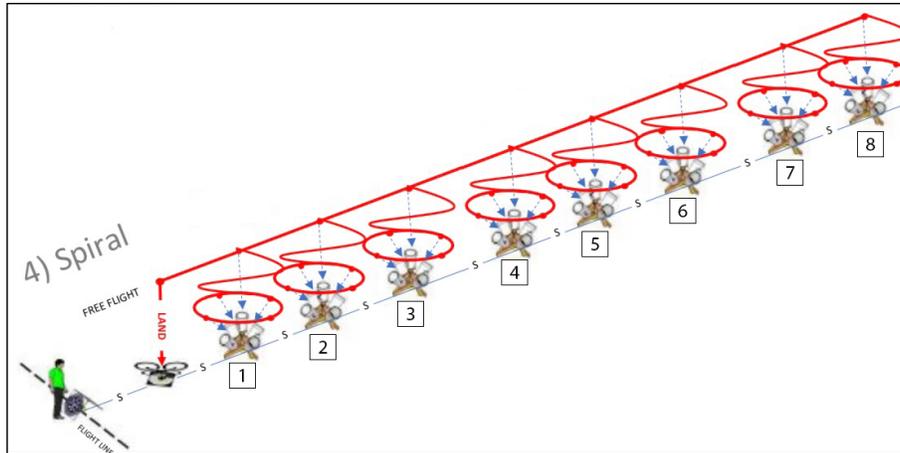
The apparatus developed for this study adapted the NIST training course to include targets containing working and episodic memory tasks. The baseline NIST course and the adapted targets were then integrated into a Mixed Reality (MR) flight simulator. The course was used in preliminary testing with two undergraduate student participants who had no prior piloting experience. Each participant completed three flights. One flight served as a baseline measure of their performance on the course to observe initial difficulty for an untrained examinee. They then completed a flight three weeks and nine weeks after their baseline flight to evaluate practice effects. In the interim between each flight, participants were completing cognitive tasks aimed to track improvements in working memory, episodic memory, and perceptual speed. These tasks were designed to be as identical as possible to the tasks used in a study conducted by Schmiedek et al. (2010) evaluating the impact of cognitive training. The length of time between sessions was derived based on this study, as well, with the intention of abbreviating the study but following the same general pattern.

Course Parameters and Technical Requirements

The flight course consisted of eight numbered omni bucket stands. Each stand had a bucket on the top of the stand, facing upwards; and four buckets on each side, facing outward at a 45-degree angle. The only change to the course layout was the use of eight target stands instead of four (see Figure 1). At the bottom of each bucket was a target with either a yellow or green ring on the perimeter. If the ring was yellow, there was a license plate in the middle. If the ring was green, there was a commonplace object in the middle. The piloting requirements of the course were to fly to each stand and take an image of the target at the bottom of each bucket in which the outer ring appeared unbroken. Participants were required to fly to the top bucket first, then back to the bucket facing the launchpad. They would then fly clockwise in a spiral maneuver around the stand to capture the remaining three buckets. Participants were reminded

to take a photo as they approached the top bucket of the first four stands. Following the fourth bucket stand, they were not given any further reminders.

Figure 1
Nist Course Structure

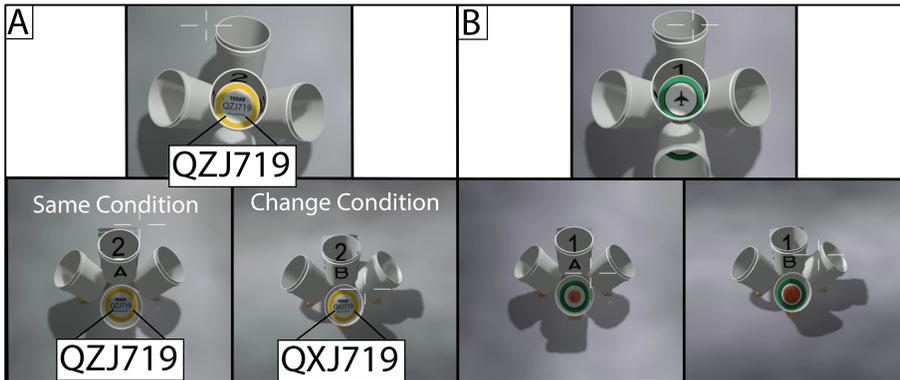


Note. Image shows the structure of the NIST course used during flights. 8 Buckets were assembled on a landing strip in the mixed reality simulator. Buckets were equally spaced apart from each other. Participants would photograph the top bucket then proceed to photograph buckets A, B, C, D. Once the final bucket was completed, participants flew back to the launch pad to land.

Integrating Cognitive Requirements

The first, third, and fifth bucket stands were intended to examine episodic memory and contained green rings and commonplace objects (see Figure 2b). Prior to beginning their flight, participants were instructed to try to remember which stand each object would be found at, as they would be asked to recall the stand number of ten of the objects at the end of the flight. The second, fourth, sixth, seventh, and eighth bucket stands were intended to examine working memory and contained yellow rings and license plates with letter-number strings of either six or seven characters (see Figure 2a). For these stands, participants were instructed to remember the license plate number in the top bucket. For each of the side buckets, they were asked to indicate whether the license plate number was the same or different than that in the top bucket. If they indicated it was different, they were asked to identify which character had changed.

Figure 2
Working Memory and Episodic Memory Stimuli



Note. Components of the NIST courses used in Experiment 1 (Panel A and B). Working Memory is tested during flight in buckets with yellow rings. Participants would examine the top bucket of each yellow ring stand and proceed to the other buckets in the stand where they would either be presented with the same bucket (represented by bucket 2a) or a bucket where 1 character had changed (represented by bucket 2b) While episodic memory is tested after the flight with the stimuli found in green ringed buckets.

Integrating the Course into a Flight Simulator

After creating targets to integrate cognitive elements, this new course was integrated into the MR flight simulator. While NIST (2020) has previously embedded the course into a simulator, it was integrated into a DJI Flight Simulator, which is more artificial in nature. Where the DJI simulator is flown using a controller and computer display, an MR simulator allows for more immersion, creating an experience that is more comparable to completing a live flight. The visual components of the simulator are also more realistic than those in a DJI simulator. Rather than simply placing a pilot in front of a computer screen, an MR flight simulator allows for the pilot to get a pilot's eye view of the aircraft while flying along with the payloads view (see Figure 3a). In addition, the MR flight simulator allows the pilot to look down and see their own hands and the physical controller for the UAS, rather than seeing an artificial construct of their hands and controller (see Figure 3b). This happens in real-time without disrupting the simulation and ensures more realistic training for the pilot. The course was designed to appear in the simulator as close as possible to how it would appear in field training, including dimensions and lane spacing, and placement on an airport runway.

Figure 3
Pilot's Point of View (POV) in the MR Simulator



Note. Panel A depicts the Pilot's POV while looking directly straight in the MR headset. The smaller window displays the payload POV which can be controlled by the pilot. The larger window in Panel A is the pilot's view from their virtual body. The Aircraft can be seen as a small black dot in the sky of Panel A. Panel B depicts the Pilot's POV in the MR simulator while looking down. The top part of the screen is part of the virtual world which is still visible while the pilot looks down at their hands in real time holding a physical controller.

Findings

On the flight task in the pretest, Subject A aligned with 48% of targets in 50 minutes, resulting in an efficiency score of .4 correct alignments per minute. During their second flight, they aligned with 97.5% of targets in 46 minutes, resulting in an efficiency score of .84 correct alignments per minute. During their final flight, they aligned with 97.5% of targets in 44 minutes, resulting in an efficiency score of .89 correct alignments per minute. This suggests they experienced an initial challenge with the task but improved substantially by their second attempt at the task and even more so by her final attempt. Subject B showed higher proficiency in the task in their pretest session, although they regressed slightly in their accuracy in their second session. They aligned with 90% of targets in 33 minutes, yielding an efficiency score of 1.09 correct alignments per minute. During their second flight, they aligned with 85% of targets in 28 minutes, yielding an efficiency score of 1.21. During their final flight, they aligned with 100% of targets in 31 minutes, yielding an efficiency score of 1.29 correct alignments per minute.

In their pretest session, Subject A scored 80% on the working memory task and 40% on the episodic memory task. In their second session, they scored 95% on the working memory task and 80% in the episodic memory task. In their final session, they scored 100% on the working memory task and 60% on the episodic memory task. Notably, these scores exhibit seemingly inconsistent levels of improvement in the episodic memory task that may be attributable to the difference in length of time between flights. Subject B scored 90% on the working memory task and 20% on the episodic memory task in their pretest. They scored 95% on the working memory task and 20% on the episodic memory task in both their second and final sessions.

While this is a pilot study with a small sample size, which limits the inferences that can be confidently made, these preliminary results yielded useful information that revealed potential shortcomings of the instrument. Given the participants' lack of experience, they performed better than expected on the flight task, suggesting the course may benefit from greater difficulty in the flight domain. Additionally, the high pretest scores observed on the working memory task suggest working memory is not challenged to the extent that would be optimal in the context of strategy development. Participants were first challenged by the episodic memory task, with one participant showing some improvement as sessions progressed, although the extent of this improvement was inconsistent. While improvements in long-term memory encoding and retrieval strategies may have played a role in this improvement, repeated exposure and opportunity to learn the course layout likely contributed, as well. It should be noted that participants completed a series of computer-based cognitive training tasks in the weeks between each flight. While this may have had potential to contribute to improvement in the cognitive tasks within the course, there was very little change in working memory for either participant. Further, the improvement in episodic memory can more reasonably be connected to the effects

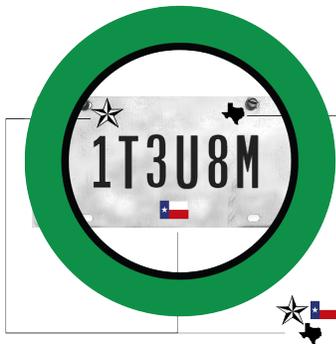
of learning the course. This is supported by the fact that Subject A's performance on the episodic memory task was better in their second flight, which was only three weeks after their first flight, in contrast to their last flight, which took place six weeks after their previous flight.

CURRENT STUDY: EXPERIMENT TWO

Procedure and Apparatus

Pilot testing suggests the current instrument shows promise in integrating cognitive skill exercises into a pre-existing training course for UAS pilots. However, the relatively high performance for each subject in one or more of the tasks within the course suggests some of the requirements may not challenge trainees to the extent that would be optimal for training purposes. Given the current study's case analysis design, the possibility stands that the two participants simply display high proficiency in these tasks. Nevertheless, the possibility that the task difficulty is merely not challenging enough was noteworthy enough that increasing the difficulty of the tasks prior to continuing testing was warranted. Just as in Experiment One, the courses for Experiment Two consisted of eight numbered omni bucket stands for each course and were laid out in the same way as in experiment one. Participants were comprised of four trained pilots and two pilots-in-training/non-pilots. Participants flew in two one-hour sessions that were spaced over approximately four days. During each session, participants flew two NIST courses. The first course flown in each session was a standard NIST course, which asked participants to fly each stand in an alternating clockwise/counterclockwise flight path. This first course was to act as a baseline for the pilot's efficiency while in the simulator. The second course in each session was an altered NIST course. The course was changed to incorporate both working and episodic memory tasks different from those in Experiment One.

Course Parameters and Technical Requirements



In the first experiment, working memory tasks were successfully integrated into the course parameters without substantially changing the completion of the flight objectives or dividing attention. Results, while limited due to sample size, suggested that the task used in experiment one may have been too simple to substantially challenge working memory, thus diminishing the ability to assess for weaknesses and facilitate strategy development in this domain. With this in mind, an updated version of the task was integrated into the course. The updated task still utilized license plates as targets. However, the contents of the plates in the new course included three symbols, which could be presented in a variety of combinations between three locations on the plate (see Figure 4).

Figure 4. License Plate Example for Experiment 2

Note. This is an example plate that was displayed in the second experiment. Three conditions existed in this experiment all of which compared buckets A-D to the top bucket. One, the string was the same as the top bucket. Two, the symbols did not change positions compared to the top bucket. Three, both the symbols and the string were different.

Additionally, instead of the letter-number string only containing one substituted character, the string was either completely different or identical. There were three categories of targets: 1) both the string and the symbol positions were different; 2) the string was the same, but the symbols were different; and 3) the symbols were the same, but the string was different. Participants determined which condition each target represented and responded with which element was the same or indicating if both elements were different. This task required the participants to retain more information and rely less on deductive reasoning for recall.

Usage of the initial altered course revealed an issue where episodic memory may not be challenged after one or two sessions due to the possibility for trainees to learn the course. As the course is intended as a continuous training instrument, minimizing learning effects is essential. Thus, in the updated course, participants were asked to circle half of the bucket stands in a counterclockwise direction instead of clockwise. This is in line with the spiral flight path of the NIST (2020), which requires participants to alternate between the clockwise and counterclockwise directions. However, for the cognitively loaded versions flight directions were randomized for each stand (e.g., a participant may be asked to fly stands one and two clockwise, three counterclockwise, four clockwise, and so on with no pattern). Both the flight path and the stimuli were changed between session one and session two to minimize learning effects, due to the short interval between sessions.

Findings

Participants' performance on the baseline course yielded an average flight time of 18.33 (SD = 7.61) minutes and an alignment score of 100%. This resulted in an average efficiency score of 2.42 (SD = 1.10) correctly aligned buckets per minute. In flight two, which consisted of a cognitively loaded course, participants' flight time (M = 19.67, SD=6.92) was increased, and alignment (M = 98%, SD= 3%) was slightly impacted. As a result of these changes, efficiency in flight two (M =2.25, SD 0.75) was lower compared to the baseline. Flight two contained the working memory task, on which participants scored 89% (SD= 8%). The overall increase in flight time is to be expected since participants must spend more time at each bucket attempting to recall and compare stimuli.

In the baseline course of session two (flight three overall), participants averaged a flight time of 12.83 (SD = 3.31) minutes and an alignment score of 99%. This resulted in an average efficiency score of 3.27 (SD = 1.02) correctly aligned buckets per minute. Flight four consisted of another cognitively loaded course, in which participants' flight time (M = 15.67, SD=2.66) was increased, and alignment (M = 98%, SD = 3%) was slightly impacted compared to the baseline. As a result of these changes, flight four's efficiency (M =2.57, SD = 0.47) was lower compared to the baseline. Flight four also included the working memory task (M =86%, SD = 7%) in which participants performed similarly to their performance in flight two. The results from session two show an overall decrease in flight time and an increase in efficiency compared to session one. It should be noted that, during the first session, participants generally seemed more confident and knowledgeable of the controls of the simulator after completing the baseline course. This is likely somewhat responsible for the changes in time and efficiency in between sessions.

Participant's scores on the episodic memory task did not vary much between courses. Participants achieved an average of 95% accuracy on the first baseline course and 98% accuracy on the second baseline course. The randomization of directions in the flight path did not seem to influence the performance on this task, with participants scoring an average of 100% on their first cognitively loaded flight and an average of 98% on their second cognitively loaded flight. The lowest average was observed on their first flight (i.e., the baseline flight with no added cognitive load). This reflects that the only major decrement in episodic memory was resolved as they became familiar with the requirements of the course.

FUTURE DIRECTIONS

It is important to note that instrument development is optimized by continuous testing and evaluation of the instrument throughout the development process. The research presented in this paper is a pilot study, and the results represent initial findings of an ongoing study. Data collection will continue to increase the sample size, as well as resume a longitudinal approach to observe the effects of cognitive training in the context of UAS pilot training. This study specifically sought out to address the issue of integrating the specific cognitive mechanisms of working and episodic memory into an existing assessment tool for UAS pilot training. While the task in Experiment Two shows promise for effectively challenging working memory, the present data does not suggest adequate measurement or training potential in the domain of episodic memory. As such, it may be prudent to incorporate more challenging episodic memory tasks in future course variations may. Future developments may also benefit from incorporating other cognitive mechanisms, more difficult technical skills, and ecologically grounded flight objectives.

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Expanded Cognitive Requirements

Once adequate tasks that challenge and facilitate strategy development in the working and episodic memory domain are established, other cognitive requirements may also be beneficial. One primary mechanism of interest is decision-making, as it is one of the most encountered sources of increased mental workload (Lercel & Andrews, 2021). Moreover, adequate decision-making and risk mitigation is among the most essential components to effectively conducting most UAS missions (Herrington et al., 2021). Adding tasks that require efficient and successful decision-making will allow the course to better encompass the requirements of UAS piloting.

Expanded Operational and Technical Requirements

A concern of the NIST (2020) may be its contrived nature. The course is designed to help operators learn to maneuver their aircraft and identify and capture targets. However, the targets and courses are artificial in nature, and may not adequately prepare pilots for the contextual components of mission completion beyond contributing to technical skill development. The primary element in current NIST courses is operating the camera payload. Other critical elements (such as communication, resource management, etc.) are not sufficiently addressed by the current program. While useful equipment and baseline metrics are provided by the instrument, specific and in-depth scenarios might be called for to enhance competency results from training (Landman et al., 2018). Although NIST provides some scenarios, the tasks involved in the quantifiable metrics in these scenarios only involve target acquisition and do not provide an assessment of success relating to any other parts of the mission.

When considering consistency in training, an obstacle may be creating scenarios relevant to a variety of contexts to guide organizations completing operations for differing purposes. Considering this, it may be valuable to create baseline scenarios that can be adapted to multiple contexts. These scenarios should include core components relevant to all pilots, such as maintaining adequate situational awareness, identifying and defining problems, adapting to unexpected changes or directions, and taking necessary steps to resolve problems. In the early stages of training, pilots may be assisted by an expert pilot to guide them through the scenario, whereas later stages of training may involve independent problem identification and solving.

The requirements of piloting may also be complicated by changes in environmental factors, such as changes in wind speed, gusts, time of day, and rain. The MR flight simulator used in this research allows for adjusting these factors. Adding more challenging environmental conditions as training progresses may allow for more broad training in a controlled environment, thus preparing pilots for challenges that are commonly encountered in the field yet cannot be adequately manipulated in field training. Providing opportunities for experiential learning that is ecologically related to commonly encountered situations can better prepare future pilots for their role (Macchiarella & Mirot, 2018).

Comprehensive Tiered Training

As previously stated, the NIST (2020) boasts the advantage of a tiered system, in which the difficulty of completing the technical requirements is increased by more complicated flight paths, obstructions in the flight lane, or acquiring more precise targets. In line with this, and in observation of the improvement seen in preliminary testing of the cognitive tasks, a tiered system relating to cognitive training may be warranted. As trainees become comfortable and proficient in one cognitive domain, an additional task may be added, or the task may increase in difficulty. Similarly, training may start without a mission scenario to establish basic proficiency, then progress to add increasingly complex scenarios. Establishing a tiered system allows for increasing workload in one domain at a time. This allows for isolation of which domain might pose certain strengths or weaknesses, facilitating structured strategy development in areas of weakness that can easily accommodate training pilots at varying skill levels. As a part of this tiered system, the course can transition to field training with a live aircraft to observe competency in a less controlled environment.

CONCLUSION

As UAS becomes increasingly prevalent, it is exceedingly important that stringent and consistent methods are applied in the training and assessment of UAS pilots. Among the most relevant topics in discussions of new pilot training is the role of flight simulators. While flight simulators afford many benefits, such as reduced financial and safety risk and fewer personnel needs, some have raised concern that the skills learned in simulators may not effectively transition

to field operations. For this reason, a training methodology that can seamlessly transition from simulators to field training is warranted. Currently only one uniform instrument, developed by the NIST (2020), exists. While this instrument may provide useful training related to the technical requirements of operating an aircraft, more complex elements of piloting are not adequately addressed. Among these requirements are effectively managing the mental workload of piloting.

The goal of this work was to develop and conduct initial testing of an instrument that both addresses the cognitive requirements of piloting and allows for seamless transition from flight simulators to field training. While the first modified course was effectively integrated into the simulator and showed promise to transition effectively to field training, the cognitive requirements of the course showed some potential weaknesses in preliminary testing. This was not unexpected, as the task did not require participants to hold enough information that would be anticipated to be taxing. In turn, the working memory task did not seem to notably challenge working memory in participants. Although the case study design limits the ability to confidently generalize these results, the lack of difficulty observed was substantial enough to warrant updating the task before continuing data collection. While the first episodic memory task initially challenged participants, it also showed the flaw of allowing for learning effects. Preliminary results with the updated version of the tasks to target these issues suggest better promise for effectively challenging working memory to a degree that will uncover weaknesses and facilitate strategy development. However, challenges in performance on the episodic memory were negligible, suggesting that the course may benefit from more adjustments in this domain.

Given the current work represents pilot testing of an instrument in early stages of development, the data presented is limited by a small sample size. As such, as concerns with the course's cognitive elements are addressed, further testing with a larger sample will be necessary to establish statistical validity of the instrument. As the current elements of the course become better addressed, it will also be valuable to consider how a tiered system may be developed relating to adding increasingly harder cognitive tasks, and more sophisticated piloting requirements. As adjustments can more easily be made in a flight simulator, its use will be instrumental in continually improving and increasing the difficulty of the course as trainees become proficient in each version. Once they have reached adequate proficiency in the complex tiers, it will be valuable to transition the instrument to field training to assess for its validity in adequately training pilots to operate outside of the simulator.

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