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Intelligence and Neuropsychological Aptitude Testing of U.S. Air Force MQ-1 Predator Pilot Training Candidates



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14. ABSTRACT The increasing role of MQ-1 Predator aircraft in support of intelligence, surveillance, reconnaissance and weapons deployment operations has resulted in the need to increase the number of fully trained pilots. To date, there are no published studies assessing the cognitive functioning of MQ-1 Predator pilots despite the important role these operators have in current unmanned U.S. Air Force (USAF) aviation. To partially fill the gap in the literature, this study obtained comprehensive computer-based intelligence testing (Multidimensional Aptitude Battery-II) and neuropsychological screening (MicroCog) on USAF MQ-1 Predator nonrated pilot training candidates who passed the initial remotely piloted aircraft (RPA) flying screening course (n=108), nonrated training candidates who failed training (n=52), as well as USAF rated pilot training candidates who cross-trained to the MQ-1 Predator from manned airframes (n=157). The results of the study revealed nonrated pilot training candidates performed in the high average to superior range on a measure of intelligence. Nonrated pilot training candidates who passed training scored higher on measures of spatial analyses/reasoning, memory for novel spatial arrangements, general visual reasoning, visual construction, general executive reasoning, and general information processing accuracy when compared with nonrated pilot training candidates who failed training. Furthermore, nonrated pilot training candidates who passed training performed substantially higher on measures of spatial analyses/reasoning, memory for novel spatial arrangements, visual reasoning, general information processing accuracy, and cognitive proficiency (a combination and accuracy of speed of information processing) in comparison to rated pilots who cross-trained from a manned airframe. The results of the study provide helpful normative data on cognitive and neuropsychological aptitudes that distinguish nonrated pilots who pass the initial RPA flying screening course. The results of the study provide insights into the aptitudes needed to adapt to the rigors of the training program, as well as the cognitive capabilities of those training candidates newly recruited for this career field. The results are considered for improving personnel selection and classification as well as aeromedical evaluation processes.					
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1.0 EXECUTIVE SUMMARY

U.S. Air Force (USAF) MQ-1 Predator pilots have a critical role in intelligence, surveillance, reconnaissance basic surface attack and close air support operations. Such pilots are perceived by subject matter experts as having high levels of intelligence and visual-spatial aptitudes necessary to pass training and adapt to operational challenges. The increasing role of MQ-1 Predator aircraft in support of intelligence, surveillance, reconnaissance and weapons deployment operations has resulted in the need to increase the number of fully trained pilots. However, to date, there are no empirically published studies assessing the cognitive functioning of this high-demand and critical career field despite the important role these operations play in current USAF aviation.

To partially fill the gap in the current literature, this study obtained comprehensive computer-based intelligence testing (Multidimensional Aptitude Battery-II) and neuropsychological screening (MicroCog) on USAF MQ-1 Predator nonrated pilot training candidates who passed the initial remotely piloted aircraft (RPA) flying screening course (n=108), nonrated training candidates who failed the training course (n=52), as well as rated pilot training candidates who cross-trained from manned airframes (n=157). Testing was obtained as part of the requirements for medical flight screening prior to candidates entering the pilot training pipeline.

The results of the study revealed nonrated pilot training candidates performed in the high average to superior range on a comprehensive, standardized measure of intelligence. Nonrated pilot training candidates who passed training scored higher on measures assessing spatial analyses/reasoning, memory for novel spatial arrangements, general visual reasoning, visual construction, general executive reasoning, and general information processing accuracy when compared with nonrated pilot training candidates who failed training. Furthermore, nonrated pilot training candidates who passed training performed substantially higher on measures of spatial analyses/reasoning, memory for novel spatial arrangements, visual reasoning, general information processing accuracy, and cognitive proficiency (a combination and accuracy of speed of information processing) in comparison to those who cross-trained from a manned airframe. Such measures of intelligence and visual-performance based aptitudes are reasonably perceived as critical to adapting to training and operational requirements.

The results suggest that cognitive aptitudes most likely predictive of performance center around visual-performance based abilities and cognitive proficiency, rather than simply high levels of general cognitive aptitude. The implications for aerospace medicine and the evaluation of USAF RPA pilot training candidates are discussed, and the results of the study are considered for improving personnel selection and classification as well as aeromedical evaluation processes for USAF RPA MQ-1 Predator pilots.

2.0 INTRODUCTION

Over the past decade, U.S. Air Force (USAF) remotely piloted aircraft (RPA) have emerged as critical assets to intelligence, surveillance, reconnaissance (ISR) and close air support (CAS) operations. Among the variety of USAF RPAs, the MQ-1 Predator and MQ-9 Reaper airframes have emerged as the most dominant weapons-bearing ISR platforms in support of theater operations. As a result, Predator/Reaper pilots have become critical assets to a uniquely challenging, high-demand, high-precision profession (1). The high demand for these missions and the unique aspects of RPA platforms that make them distinct from conventional manned

airframes have led the USAF to seek training candidates from outside the traditional pool of pilots who are trained and rated to fly manned aircraft. RPA platforms are different from manned airframes, and little is known about the skills and abilities that are necessary to pilot these missions successfully. The effective selection of Predator/Reaper pilot training candidates for such aircraft is essential to successful training and operational performance. Although RPA operations are largely centered on advanced satellite and computer-based technology, subject matter experts (SMEs) perceive cognitive aptitudes have a key role in successful performance and adaptation to the demands of Predator/Reaper operations (1).

2.1 Aerial Combat Demands for MQ-1 Predator Operations

Over the past decade, the MQ-1 Predator has served a variety of roles in providing real-time information to commanders for identifying fixed and moving targets, tracking enemy movements and assets, tracking and/or eliminating enemy combatants, catching insurgents planting roadside bombs, locating and destroying weapons caches, directing and protecting ground forces, safeguarding convoys, augmenting manned-strike missions, and surveying post-strike battle damage. Such aircraft provide a wide range of ISR and CAS capabilities in support of battlefield operations around the globe. USAF leadership lauds the role of the MQ-1 Predator as a complex force multiplier with dynamic air combat capabilities with the advantage of shielding crew members from the traditional aviation-related threats to personal safety (2).

Within the last 5 years, the number of MQ-1 Predator missions and combat air patrols sustained 24 hours a day has increased significantly. For example, the number of weapons strikes conducted by MQ-1 Predator/MQ-9 Reaper aircraft in Afghanistan has progressively increased every year for the past few years, while the number of strikes provided by manned airframes has progressively declined. Since 2009, there have been approximately 1160 weapons strikes performed by RPA aircraft in Afghanistan. The shift in weapons strikes is reflective of USAF aviation operations becoming more reliant upon the decisive advantages of RPA capabilities. The success of the MQ-1 Predator as well as other RPA airframes (e.g., MQ-9 Reaper and RQ-4 Global Hawk) has influenced budget allocations for such aircraft beyond amounts requested by USAF leadership (3). The acquisitions budget is a demonstration of devotion to the vision of USAF leader that RPA operations will increasingly take over missions traditionally accomplished by manned airframes during this next century (2,4).

Despite advancements in computer-based technology and the automated nature of certain aspects of RPA operations, USAF Predator pilots are central to effective surveillance, targeting, weapons deployment, and battle damage assessment of enemy combatants and assets. Such pilots perform a wide range of manual and computer-based tasks to actively and/or passively control, maneuver, and fly the aircraft during planned, unplanned, and in-flight emergencies. The following are examples of MQ-1 Predator pilot duties reported in qualitative studies based upon input from USAF training cadre and rated MQ-1 Predator operators (Nagy JE, Kalita SW, Eaton G, *U.S. Air Force Unmanned Aircraft Systems Performance Analyses, Predator Pilot Front End Analysis (FEA) Report*, SURVIAC-TR-06-203, Feb 2006; available through the Defense Technical Information Center to U.S. Government agencies and their contractors only) (1).

- Performing preflight and in-flight mission planning activities in accordance with unified combatant command and theater rules of engagement
- Understanding tactics, techniques, and procedures for friendly and enemy air order of battle assets
- Receiving, interpreting, extracting, and disseminating relevant air tasking orders, airspace control orders, and spins information
- Ensuring airframe and supporting ground control systems for controlling the aircraft are operating efficiently and effectively
- Performing checklists and monitoring systems controls during aircraft launch and recovery operations
- Flying the aircraft en route to airspace of national interest while coordinating with air traffic control, as well as other aircraft and aircrew
- Maneuvering the aircraft to gather surveillance and reconnaissance data over targets and areas of interest
- Maneuvering the aircraft into strategic positions for the deployment of weapons (e.g., CAS of ground troops)
- Assisting in air navigation, air order of battle integration, fire control planning, and determining effective weapons control and delivery tactics to achieve mission objectives
- Receiving target briefs for weapons delivery and conducting battle damage assessments
- Maintaining situational awareness to target imagery, friendly and enemy orders of battle, and offensive and defensive capabilities from various sources
- Assembling target information, locating forces, and determining hostile intentions and possible tactics

As can be surmised from the list above, USAF Predator pilots form a unique profession requiring quick, accurate, and sustained vigilance and decision-making in response to multiple sources of real-time visual and auditory information. They must process and translate visual and auditory input into spatial imagery while maintaining constant vigilance and situational awareness. The analyses of real-time information (auditory and visual), task prioritization, and complex decision-making are perceived to require high levels of cognitive functioning. Higher cognitive functioning has been found to be associated with successful completion of USAF pilot training and job performance (5,6), but similar analyses have not been conducted on RPA pilots and trainees.

2.2 Accession Sources for MQ-1 Predator Pilot Trainees

USAF MQ-1 Predator pilots are drawn from three sources: (1) operationally experienced rated pilots who cross-train from a manned airframe (e.g., F-16, F-15, B-2, C-130, C-117, KC-135), (2) operationally inexperienced manned airframe pilots who have recently graduated from Specialized Undergraduate Pilot Training (SUPT), and (3) nonpilot commissioned officers (e.g., acquisitions, logistics, security forces, and engineering) who are cross-training and/or recently commissioned to serve in the Air Force after completing a 4-year college degree.

2.2.1 Operationally Experienced Cross-Trained Rated Pilots. A significant accession for MQ-1 Predator pilots are rated pilots from manned airframes who have been selected to “cross-train” into the RPA career field. Operational commanders and leadership have relied upon rated

pilots because of their flying knowledge and skills. Operationally experienced pilots from this selection pool come from different airframes (e.g., fighter, bomber, tanker, transport, and surveillance) with various operational experience levels.

2.2.2 Operationally Inexperienced Rated Pilots. The second accession source is pilots who recently graduated from SUPT. SUPT is 52 weeks of pilot training in a manned aircraft, and SUPT students are officially recognized as USAF rated pilots at the end of their training. Normally, an SUPT graduate would be selected for a manned airframe and continue on to advanced training in a manned aircraft. However, to fill the manpower gap of qualified pilots and meet the growing demand for RPA operators in support of battlefield operations, USAF leadership assigns a number of SUPT graduates each year to the MQ-1 Predator airframe.

2.2.3 Nonpilot Commissioned Officer Nonrated Pilots. The third accession source draws from USAF nonrated, nonpilot commissioned officers who are either (1) experienced and rated USAF nonpilot aircrew (e.g., panel navigator, electronic warfare officer, weapons system officer, or air battle manager) or from (2) nonflying career fields (e.g., acquisitions, logistics, security forces, engineering, services, space, and missile duty). Most nonrated pilot training candidates are recent graduates from a 4-year college seeking commissioning as an officer in the USAF. This accession source was primarily developed to meet the critical shortage of RPA pilots due to the increasing demand for RPA operations across the globe. The goal of training nonpilot officers is to alleviate the burden of rated pilots (operationally experienced and inexperienced) from manned airframes from having to fill the shortage in qualified RPA pilots. It is possible for this nonpilot accession source to become the primary selection pool of future USAF RPA pilot training candidates.

2.3 Training Pipeline for MQ-1 Predator Pilots

This section reflects modifications and changes to the brief summary of the RPA training pipeline as originally reported in an earlier study (1). The section does not include changes or modifications to the training pipeline that may have occurred after July 2012.

The Air Education and Training Command developed a formal training pipeline for RPA pilot training candidates. Training to become a rated, fully qualified MQ-1 Predator pilot consists of several phases. However, where an RPA pilot training candidate enters the pipeline depends upon his/her accession source and flying experience (see Figure 1).

Nonrated pilot training candidates enter the RPA pilot training program earlier than rated pilot trainees (i.e., experienced pilots cross-training from a manned airframe and inexperienced pilots who recently graduated from SUPT). Nonrated pilot RPA training candidates attend RPA Flight Screening (RFS) for 2 months. The goal is for nonrated pilot training candidates to learn the fundamentals of flying and aerodynamic principles, become familiar with aircraft instruments, complete solo flights as a pilot in a manned airframe, and gain knowledge and confidence as a pilot in general. The nonrated pilot trainees complete approximately 40 hours of training during this phase that includes dual flying, cross-country flying, night flying, simulated instrument flying, and solo flying time.

Once nonrated pilot training candidates complete this phase of training, they enter the 2-month RPA Instrument Qualification (RIQ) course. This course is designed to teach RPA instrument-related skills. The development of such skills is essential to flying in both national

and international airspace. This course is essential for understanding how the RPA platform operates in an environment where thousands of aircraft are flying in accordance with instrument flying required flying rules. This training provides nonrated pilot training candidates with the skills to operate in the national air space. Rated AF pilots (whether experienced or inexperienced) have already acquired these skills and do not attend RIQ.

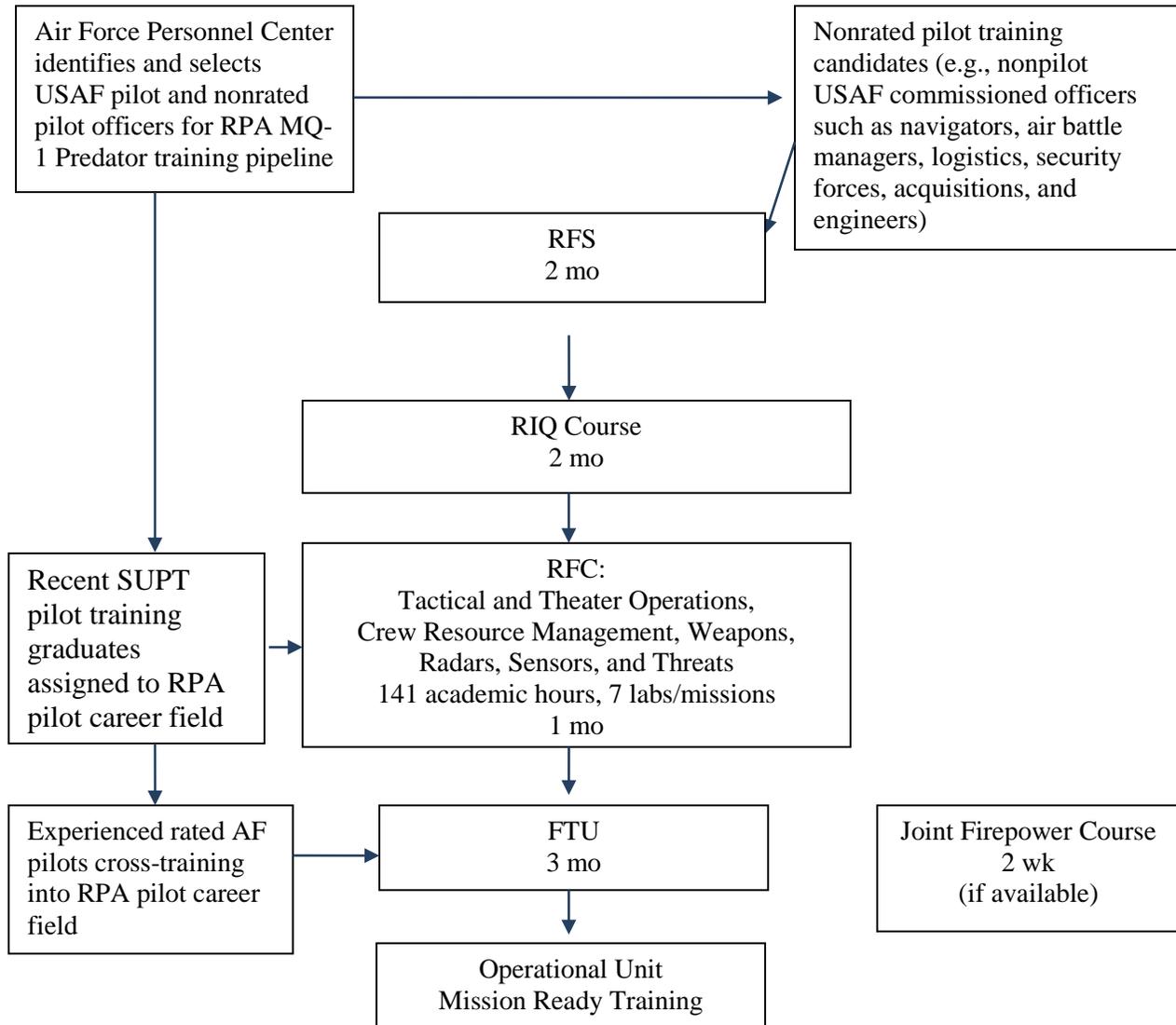


Figure 1. General Training Pipeline Program Flow for RPA Pilot Training Candidates (as of July 2012)

After completion of RIQ, nonrated pilot training candidates join recent graduates from SUPT who have been assigned to become RPA pilots. Both groups undertake 141 hours of academics and seven labs/missions in the RPA Fundamentals Course (RFC). Academic instruction includes training on tactical and theater operations, rules of engagement, operating in

battle space, weapons, radars, sensors, as well as crew resource management. Aviation training at this time is essentially over and the focus is on combat fundamentals and conducting RPA ISR in regions of interest (e.g., rules of engagement, threats, etc.).

After completion of RFC, all RPA pilot training candidates enter 3 months of instruction in the Formal Training Unit (FTU). Air Combat Command (ACC), a major command of the USAF, controls FTU training. This is the specific platform training needed to operate the MQ-1 Predator, MQ-9 Reaper, or RQ-4 Global Hawk. Pilot training candidates learn not only the specific flight skills needed but also how to employ the aircraft and sensor technology in a real world environment. ACC strives to make pilots mission qualified at graduation.

After graduation from the FTU, all RPA pilot training candidates are assigned to their operational reconnaissance squadron and enter Mission Ready (MR) training. MR instruction occurs at the RPA operational ACC, Air Force Special Operations Command, Air National Guard, or USAF Reserve unit to which the pilot training candidate is assigned to support. MR instruction is multi-phase training (based on an officer's prior skill sets and experience). This training is composed of three phases and can vary according to the specific training instruction requirements of the unit. A trainee is considered mission *ready* when he or she is perceived as being professionally and technically proficient in supporting ISR and combat-oriented missions.

At some point in time, RPA pilot training candidates may have the opportunity to attend the Joint Firepower Course. The course is operated by ACC and provides instruction on concepts, doctrine, control systems, tactics, techniques, and procedures by which air and surface combat forces plan, request, coordinate, and control joint firepower among military branches on the ground, air, and sea. The course teaches pilot trainees how to coordinate the mission, pass on information, and receive orders in joint operations. The goal is to teach pilot trainees how to integrate RPAs into joint combat operations that involve identifying, targeting, and destroying enemy combatants and assets.

Overall, the training pipeline is to equip candidates with the skills for adapting to the operational demands of flying RPA aircraft in various parts of the globe, navigating through international airspace, while operating in restricted and unrestricted environments, and passing the aircraft to launch and recovery teams also located in other parts of the world. MQ-1 Predator pilot duties are considered high risk, high demand, despite the computer-based and automated nature of the platform (1). Training candidates must acquire a unique skill set within a restricted period of time and effectively demonstrate a high level of proficiency in support of real-time military ISR and CAS operations. Training attrition of RPA pilots comes at a great cost to USAF initiatives seeking to expand RPA support across the globe to combatant commanders and other Department of Defense agencies.

Reducing training attrition at various points in the training pipeline is critical. It is important to note that all training attrition for nonrated pilot training candidates occurs in the RFS course. Based upon discussions the authors of this study have had with USAF Air Education and Training Command leadership and USAF RPA pilot training pipeline managers, there are no reported cases of performance attrition following RFS.

2.4 Cognitive Aptitudes of USAF Pilots

For the purposes of this study, cognitive aptitude is distinct from *knowledge* and *skill*. "Cognitive aptitude" refers to the inherent capabilities (e.g., speed and accuracy of information processing, spatial analyses, visual construction, visual learning, working memory,

attention/concentration, etc.) that must be present to acquire the knowledge and skills needed to successfully operate as a pilot and adapt to the unique demands of the RPA platform. The terms “knowledge” and “skill” refer to those aspects of functioning gained through various forms of experience, education, and training.

Several studies have assessed the cognitive capabilities of USAF pilots from manned airframes (5-8). A meta-analysis of military pilot selection literature over the past 20 years concluded that cognitive aptitudes relevant to pilot performance include general intelligence, general verbal and quantitative abilities, dexterity, perceptual speed and information processing, reaction time, and visual-spatial abilities (9). Additional studies have found that USAF pilots score in the high average to superior range on verbal and visual-performance based intelligence tests (6,8). The finding that USAF pilots have high average to superior levels of intelligence is not surprising given cognitive aptitude is a strong predictor of completing pilot training (10,11). Based upon the literature, high levels of intelligence and cognitive aptitude appear critical to training and adapting to the operational demands of military flying.

However, literature on cognitive aptitudes specific to the performance of weapons-bearing RPA pilots and pilot training candidates is limited. A comprehensive review of the basic knowledge, skills, and abilities of RPA pilots in general (civilian and military) identified several cognitive aptitudes as key to performance, including situational awareness, vigilance, spatial analysis, reasoning, speed of information processing, visual tracking, searching, and scanning (12). The results of this review were similar to other studies that assessed the job tasks and skills required for military-specific RPA aircraft, such as the Pioneer (13,14) and Global Hawk (Nagy JE, Muse K, Eaton G, Phillips A, *U.S. Air Force Unmanned Aircraft Systems Performance Analyses: Global Hawk Pilot and Sensor Operator Front End Analysis (FEA) Report*, SURVIAC-TR-10-041, Survivability/Vulnerability Information Analysis Center, Jan 2007; available through the Defense Technical Information Center to U.S. Government agencies and their contractors only).

The cognitive aptitudes identified in the Pioneer and Global Hawk studies are similar to the aptitudes reported in a comprehensive analysis of MQ-1 Predator pilot tasks completed by the United Kingdom Royal Air Force (UK RAF) (Bailey M, *Predator Pilot and Sensor Operator Selection Test Batteries*, Royal Air Force Technical Report, Cranwell Royal Air Force Base, England, 2009; available by request only). An analysis of MQ-1 Predator pilot tasks conducted by the UK RAF identified several specific cognitive aptitudes critical to performance including perceptual reasoning and processing, short-term memory, spatial reasoning, symbolic reasoning, central information processing, psychomotor dexterity, and reaction time. The authors concluded that cognitive aptitudes contributed to about two-thirds of the factors associated with MQ-1 Predator pilot training and job success in their sample of RPA pilots.

More recently, the USAF School of Aerospace Medicine completed a study of USAF MQ-1 Predator pilot cognitive aptitudes (1). The study was a qualitative analysis based upon interviews (n=85) with SMEs, MQ-1 Predator training instructors, line commanders, and rated pilots. SMEs were asked to describe an array of cognitive aptitudes perceived as essential for pilot training candidates and incumbents to possess to successfully complete major job tasks and adapt to the rigorous occupational demands. Based on a qualitative analysis of SME data and interviews, the authors identified several cognitive aptitudes perceived as critical to performance, which included cognitive proficiency, visual perception, spatial processing, memory, reasoning, and psychomotor processing (Table 1). The results of the USAF School of Aerospace Medicine study revealed several cognitive aptitudes consistent with the findings from the UK RAF.

However, aside from the theoretical and qualitative studies above, the empirical data regarding cognitive aptitudes specific to the performance of MQ-1 Predator pilots are limited.

Table 1. Cognitive Aptitudes^a Considered Critical to MQ-1 Predator Pilot Performance According to Rated USAF RPA Pilot Training Instructors and Rated Pilots^b

Facet	Attribute
Cognitive Proficiency	Speed and accuracy of information processing
Visual Perception	Visual acuity, scanning, and discrimination Visual recognition, tracking, and analysis
Attention	Vigilance to multiple sources of visual and auditory information (<i>situational awareness</i>) Sustained and divided attention to visual and auditory information
Spatial Processing	Spatial analysis and orientation Ability to create 4-dimensional mental representations from 2-dimensional images (spatial reasoning and construction)
Memory	Visual and auditory memory (working, immediate, and delayed) Spatial and psychomotor memory (working, short-term, and delayed)
Reasoning	"Real-time" general and deductive reasoning (<i>problem-solving</i>) Task prioritization Carefully and quickly assessing risk, likely outcomes, and potential repercussions (<i>forward thinking</i>) Cognitive flexibility (<i>thinking outside the box</i>)
Psychomotor Processing	Fine motor dexterity and reaction time Psychomotor-spatial coordination and accuracy

^aThe Cognitive domain refers to intellectual mental functions and information processing aptitudes essential to the acquisition and application of knowledge. Common aspects of cognition include perception, attention, memory, comprehension, reasoning, learning, and problem-solving.

^bAdapted from Chappelle, McDonald, and McMillan (2011) (1).

2.5 Aeromedical Importance of Normative Intelligence and Neuropsychological Test Data

Although there may be controversy over the aspects and specific cognitive abilities that constitute the *right stuff* for a USAF RPA pilot, there is little argument about cognitive deficits that represent the *wrong stuff*. A person with low general cognitive ability and borderline functioning in visual-spatial, visual learning, or visual-constructive abilities should likely not engage in RPA pilot duties. Such difficulties in cognitive functioning can conceivably create problems for military readiness and elevate the risk for an aviation mishap. However, while an RPA pilot training applicant's general cognitive ability may be estimated from his or her responses to the Air Force Officer Qualifying Test, there are no clear data regarding the distribution of cognitive test scores for RPA pilot training candidates who pass and those who fail training. Furthermore, the Air Force Officer Qualifying Test does not directly assess the visual-spatial aptitudes that have been reported by SMEs to be essential to performance (1).

Having a clear understanding of the level and distribution of intelligence and neuropsychological testing scores among successful USAF MQ-1 Predator pilots will help improve aeromedical evaluation processes. Having a better understanding of what cognitive aptitudes are predictive of performance will also help flight medicine providers better focus their evaluations on the type of aptitudes critical to adapting to operational demands.

This lack of information is problematic for USAF civilian and active duty psychologists and psychiatrists who are regularly called upon to assess the cognitive disposition of training candidates and assist flight surgeons in making recommendations about a candidate's fitness for RPA pilot duties. USAF aeromedical policy requires intellectual assessments for a number of neuropsychological and psychiatric conditions (15). An aeromedical evaluation of an RPA pilot training candidate's cognitive functioning is required when there is a history of cognitive difficulties (e.g., memory, attention, reasoning, information processing) stemming from a head injury, medical illness (e.g., bacterial meningitis), developmental disorder (e.g., attention deficit and hyperactivity, learning disorder), or emotional problems (e.g., depression, anxiety). In general, intelligence and cognitive aptitude testing is a common part of an aeromedical evaluation when there is concern regarding a pilot candidate's cognitive disposition related to medical and/or psychological illness/injury. Although such testing is required, no empirical, normative data exist for successful RPA pilots.

As a result, RPA pilot training candidates (or incumbents) seeking waivers (i.e., medical clearance for the pilot to return to flying duties) may be unfairly evaluated if they are clinically compared with rated pilot normative data from manned airframes. Use of general population norms and/or rated pilot norms for manned airframes may not clearly articulate a training candidate's (or incumbent's) suitability for the demands and rigors of the RPA platform. Furthermore, not all psychologists who assess these pilots have training in aviation psychology. It is vital the psychologists who are assessing these individuals and making critical decisions about these pilots' careers have appropriate aviation-specific norms for this population. As a result, there is a strong clinical and aeromedical need for establishing normative data on the general intellectual and cognitive functioning of RPA pilot training candidates who succeed versus fail training, as well as for identifying differences between rated pilots from manned and unmanned airframes.

In addition to aiding medical personnel with assessment and disposition determinations, understanding the general intellectual ability and cognitive aptitudes associated with successful completion of RPA pilot training will help to shape aeromedical policy and selection criteria. The highly automated nature of the RPA platform results in significant amounts of streaming real-time video data and auditory information that the pilot processes and that require continuous and complex responses. It is unknown if this type of environment demands a different set of cognitive skills and abilities than that required by pilots of manned aircraft. Greater awareness of the role of cognitive functioning of successful pilot training candidates may help to further develop effective aeromedical policy.

2.6 Purpose of the Study

The purpose of this study is to examine computer-based intelligence and neuropsychological aptitudes of nonrated (no prior aviation experience) USAF RPA pilot candidates who successfully completed the initial phase of training. The objectives are to (a) obtain normative intelligence data on nonrated pilot training candidates recruited for MQ-1

Predator pilot training, (b) compare nonrated pilot training candidates who passed RFS with nonrated candidates who failed, and (c) compare nonrated pilot training candidates who passed RFS with experienced USAF rated pilots who cross-trained into the MQ-1 Predator airframe. The normative distribution of test scores along with differences that distinguish successful RPA pilot training candidates from a nonpilot accession source is critical to understanding the cognitive aptitudes that influence training performance. Additional information on how nonrated pilot training candidates recruited directly into the MQ-1 Predator pilot career field differ and are similar to USAF rated pilots who cross-trained into the same career field may be helpful for recruitment and personnel selection and aeromedical evaluation processes.

3.0 METHODS

3.1 Subjects

This study evaluated USAF MQ-1 RPA pilot candidates selected for training over a 24-month period. The purpose and methodology to use data from psychological testing during baseline testing were reviewed and granted exemption from the Wright-Patterson Air Force Base Institutional Review Board and assigned protocol number F-WR-2008-0021-E.

In total, 108 nonrated RPA pilot training candidates who passed the initial phase of training (i.e., RFS) were included in this study. The average age for this group was 25.97 years (standard deviation (SD) =4.30). The majority of the group was male (96.3%). Participants reported being from the following racial categories: Caucasian (84.2%), African-American (5.6%), Asian/Pacific Islander (3.7%), Hispanic (2.8%), and “other” (0.9%).

Fifty-two nonrated RPA pilot training candidates who failed the initial phase of training were included in this study. The average age for this group was 24.45 years (SD=2.95). The majority of this group was male (82.7%). Participants reported being from the following racial categories: Caucasian (65.4%), African-American (3.8%), Asian/Pacific Islander (15.4%), Hispanic (9.6%), and “other” (3.8%).

In total, 157 USAF rated pilots from manned airframes who successfully cross-trained into the RPA pilot career field were included in this study. Their average age was 22.34 years (SD=2.66, based on n=149), and the majority was male (94.9%). Racial distribution was Caucasian (85.4%), Hispanic (3.8%), African-American (3.8%), Asian/Pacific Islander (1.9%), and Indian (0.6%).

3.2 Measures

3.2.1 Multidimensional Aptitude Battery-II (MAB-II). The MAB-II is a broad-based test of cognitive functioning (MAB-II) (16). The content and structure of the test were fashioned after the Wechsler Adult Intelligence Scale, which is the most widely used individually administered test of cognitive functioning and intelligence (17). The MAB-II has 10 subtests that are each 7 minutes long, and all items have 5 multiple-choice responses (Table 2). Administration of this test produces verbal (VIQ), performance (PIQ), and full-scale intelligence quotient (FSIQ) scores, which are global measures of cognitive functioning. The test is separated into verbal abilities (i.e., subtests of information, comprehension, arithmetic, similarities, and vocabulary) and visual-performance based abilities (i.e., subtests of digit symbol coding, picture completion, spatial analyses, picture arrangement, and object assembly). The MAB-II normative subtest

scores for the general population have a mean of 50 and an SD of 10. The normative VIQ, PIQ, and FSIQ scores in the general population have a mean of 100 and an SD of 15. The MAB-II manual has well-documented internal consistency, test-retest reliability, and validity coefficients.

Table 2. MAB-II Factors, Subtests, and Descriptions (16)

Subscale	Description
Verbal Intelligence Subscales	
Information (inf)	General fund of knowledge; long-term memory
Comprehension (com)	Social reasoning and comprehension
Arithmetic (ari)	General and numerical reasoning; problem-solving
Similarities (sim)	General reasoning and problem-solving
Vocabulary (voc)	Flexibility and adjustment to novelty, reasoning, abstract thought, long-term memory
Visual-Performance Intelligence Subscales	
Digital Symbol (ds)	Adaptation to new set of demands; visual learning and coding, figural memory, and speed of information processing
Picture Completion (pc)	Visual attention to detail; knowledge of common objects; perceptual and analytical skills
Spatial Score (sp)	Ability to visually and mentally rotate abstract 2-dimensional images of objects in different positions; figural-domain reasoning
Picture Arrangement (pa)	Visual reasoning; ability to identify a meaningful sequence; social intelligence; perceptual reasoning
Object Assembly (op)	Visualization and visuo-construction skills; perceptual analytical skills needed to identify a meaningful object from left-to-right sequence

3.2.2 MicroCog. The second computer-based test is the MicroCog (18). This test was designed to screen specific neurocognitive aptitudes. It is composed of 18 subtests that are, in turn, combined to yield 5 first-level indices (i.e., attention and mental control, reasoning and calculation, memory, spatial analyses, and reaction time; see Table 3). The scores from the five first-level indices are aggregated to compute second-level indices regarding speed of information processing and accuracy of information processing. The scores from the second-level indices are then re-weighted to create third-level indices for general cognitive functioning and general cognitive proficiency (i.e., a weighted assessment of a person’s overall cognitive functioning that also accounts for speed of information processing). The second and third levels are differentially weighted aggregates of scores from the first-level indices. The MicroCog is individually administered and scored via a computer. Multiple-choice items with varying numbers of response options and free-response items are presented for each test. General speed of information processing is measured by reaction time to each item. The five first-level indices, two second-level indices, and two third-level indices of the MicroCog *each have a mean of 100*

and SD of 15. These scores have been statistically adjusted for age and level of education. The manual for the MicroCog has well-documented internal consistency, test-retest reliability, and validity coefficients (18).

Table 3. MicroCog Index Descriptions (18)

Index	Description
1st-Level Indices	
Spatial Processing (spatial)	Memory for novel spatial arrangements, visuo-perceptual ability
Attention/Mental Control (atten)	Concentration, span of attention, diligence, persistence, resistance to interference
Reasoning/Calculation (reason)	Inductive reasoning, cognitive flexibility, concept formation
Memory (memory)	Visually oriented short-term memory (storing information for a brief period - a few minutes) and long-term memory (storing information over a 30- to 45-minute period)
Reaction Time (react)	Length of psychomotor time between presented stimulus and response, readiness to respond, vigilance, attention
2nd-Level Indices	
Information Processing Speed (ipsss)	General information processing speed
Information Processing Accuracy (ipass)	General information processing accuracy
3rd Level-Indices	
General Cognitive Functioning (gcfss)	Overall general cognitive functioning/capability
General Cognitive Proficiency (gcpss)	Combination of cognitive speed and accuracy

3.3 Nonrated Pilot Candidate Training Outcomes: Pass vs. Fail

Pilot training candidates from the nonrated pilot accession source who failed RFS due to performance problems or who self-eliminated were grouped into the “training fail” category. Medical disqualifications were not included in this category. The vast majority of training failures occurred during RFS. This is the first 2 months of the training program where nonpilot training candidates learn the fundamentals of flying and aerodynamic principles, become familiar with aircraft instruments, complete solo flights as a pilot in a manned airframe, and gain knowledge and confidence as a pilot in general. There have been no reported training failures following completion of RFS.

Pilot training candidates who successfully completed the entire RPA pilot training program and became qualified to fly the MQ-1 Predator were grouped into the “training success” category. These training candidates received operational assignments to fly the MQ-1 Predator

and were sent to MR training at an active duty AF operational unit within ACC or the Air Force Special Operations Command.

USAF rated pilots (experienced and inexperienced) from manned airframes and assigned to MQ-1 Predator training and who successfully completed such training were also included in the study. These pilots were either operationally experienced or inexperienced and rated to fly manned airframes. Due to the needs of the USAF, these pilots were assigned to cross-train into the RPA career field to fill existing RPA pilot manpower gaps.

3.4 Procedure

The sample of pilot candidates in this study was administered both the MAB-II and the MicroCog as a routine part of medical flight screening prior to attending pilot training (for either unmanned or manned airframes). The variables chosen for analysis were those reported and interpreted in clinical and other medical settings assessing suitability for flying. These included the 10 subtests and 3 composites of the MAB-II and the first-, second-, and third-level index scores of the MicroCog. The baseline intelligence testing and neuropsychological aptitude screening were downloaded into a spreadsheet for analyses. The testing during medical flight screening was matched with pass/fail training outcome data provided by training pipeline managers within the Air Education and Training Command.

4.0 RESULTS

As stated previously, this study was designed to assess differences between nonrated RPA pilot candidates who passed pilot training, nonrated RPA pilot candidates who failed pilot training, and USAF rated RPA pilots who cross-trained into the MQ-1 pilot career field. Analyses performed assessed differences among computer-based intelligence testing with the MAB-II regarding verbal and visual-performance based subscales and indices regarding VIQ, PIQ, and FSIQ. Analyses performed also assessed differences among computer-based neuropsychological testing with the MicroCog regarding first-, second-, and third-level indices assessing various cognitive aptitudes.

4.1 Calculating Group Means

The first step of analyses was to run descriptive analyses to obtain group performance on each of the computer-based performance measures. Table 4 presents the means and standard deviations for each of the three groups of interest relative to the performance on the MAB-II and MicroCog. MAB-II intelligence test scores were based upon age-corrected norms and the MicroCog neuropsychological test scores were based upon age- and education-corrected norms.

4.2 Assessing Multicollinearity Across Subtests within the MAB-II and MicroCog

The second step of analyses involved assessing the relationship among the variables of interest via independent correlation coefficient matrices for the MAB-II and MicroCog. This was performed to determine if multicollinearity existed within the measures of each test that required any adjustment to appropriately analyze the data. Tables 5 and 6 present Pearson correlations between subscales and indices within the MAB-II and MicroCog. While there are significant correlations at $p < .010$, they are small and there were no violations of multicollinearity

based upon tolerance or variance inflation factor. Additionally, a review of the pattern of correlations did not indicate bias in a specific direction.

Table 4. Between Group Means and Standard Deviations for Training Candidates

Indices & Subscales	Nonrated Training Candidates Who Passed (n=108)		Nonrated Training Candidates Who Failed (n=52)		Rated Pilots Who Cross-Trained (n=157)	
	Mean	SD	Mean	SD	Mean	SD
MAB-II (Age Corrected)						
Full-Scale IQ	122.19	6.16	118.23	6.35	120.94	6.29
Verbal IQ	118.17	6.19	115.87	5.99	119.45	5.85
Performance IQ	123.41	8.33	118.42	8.58	119.66	8.31
Verbal Intelligence Subscales						
Information	65.52	5.96	63.06	6.17	67.06	5.15
Comprehension	59.37	3.67	57.79	3.88	59.72	4.17
Arithmetic	61.03	6.20	58.92	6.98	60.39	7.57
Similarities	59.48	4.94	58.79	4.35	60.13	3.99
Vocabulary	58.25	6.48	57.81	6.76	60.26	6.77
Performance Intelligence Subscales						
Digit Symbol	68.01	6.33	66.87	6.73	66.95	6.98
Picture Completion	60.30	6.29	58.73	6.40	60.17	6.43
Spatial Analyses	62.95	6.10	59.77	5.44	59.80	6.54
Picture Arrangement	54.81	8.54	51.08	9.28	51.60	7.91
Object Assembly	63.16	5.51	60.38	5.88	62.11	4.75
MicroCog (Age & Education Corrected)						
1st-Level Indices						
Spatial Processing	110.70	10.01	107.94	10.92	106.07	10.36
Attention/Mental Control	104.47	10.67	99.92	12.33	102.50	12.54
Reasoning/Calculation	99.30	10.77	93.44	13.42	96.65	12.73
Memory	111.57	13.75	108.19	13.31	110.66	13.94
Reaction Time	100.69	11.69	95.87	12.10	98.15	13.41
2nd-Level Indices						
Processing Speed	107.23	11.53	103.25	14.21	104.84	13.30
Processing Accuracy	101.55	12.01	96.15	11.29	97.83	13.43
3rd-Level Indices						
General Functioning	117.56	14.04	110.15	15.20	107.99	14.80
General Proficiency	107.19	9.26	103.69	9.66	103.91	10.31

4.3 Assessing Between Group Differences

The third step was to conduct analysis of variance (ANOVA) tests on the MAB-II intelligence test regarding scores for the verbal- and performance-based subscales, as well as indices (VIQ, PIQ, and FSIQ). Subsequent Dunnett's post-hoc tests were completed after each statistically significant ANOVA test to identify where statistically significant between group differences occurred. Additionally, Cohen's *d* effect sizes were calculated for each statistically significant post-hoc comparison to evaluate the magnitude of the difference in group scores. When assessing between group differences following a statistically significant ANOVA, the authors of this study set a priori criteria of an effect size of .40 or greater and power at .75 or greater for both the MAB-II and MicroCog.

Table 5. Pearson Correlations Assessing Multicollinearity Across Subtests within the MAB-II

Indice & Subscales	Pearson Correlations				
Verbal IQ	1.00				
Performance IQ	.30 ^a				
Verbal Intelligence Subscales					
Information	1.00				
Comprehension	.37 ^a	1.00			
Arithmetic	.24 ^a	.16 ^a	1.00		
Similarities	.41 ^a	.39 ^a	.12	1.00	
Vocabulary	.57 ^a	.38 ^a	.17 ^a	.44 ^a	1.00
Performance Intelligence Subscales					
Digit Symbol	1.00				
Picture Completion	.14 ^a	1.00			
Spatial Analyses	.35 ^a	.25 ^a	1.00		
Picture Arrangement	.24 ^a	.37 ^a	.30	1.00	
Object Assembly	.22 ^a	.33 ^a	.47 ^a	.45 ^a	1.00

^a*p* < .01

Table 6. Pearson Correlations Assessing Multicollinearity Across Subtests within the MicroCog

Indices	Pearson Correlations					
1st-Level Indices						
Spatial Processing	1.00					
Attention/Mental Control	.31 ^a	1.00				
Reasoning/Calculation	.22 ^a	.28 ^a	1.00			
Memory	.14 ^a	.27 ^a	.33 ^a	1.00		
Reaction Time	.23 ^a	.18 ^a	.14 ^a	.07	1.00	
2nd-Level Indices						
Information Processing Speed	1.00					
Information Processing Accuracy	-.10	1.00				
3rd-Level Indices						
General Functioning	1.00					
General Proficiency	.83 ^a	1.00				

^a*p* < .01

See Table 7 for the results of analyses assessing between group differences on the MAB-II. Overall, nonrated pilot training candidates who passed RFS, when compared with both other groups, scored higher on the MAB-II visual-performance based index (PIQ), as well as the MAB-II subscales of Information (i.e., general fund of knowledge), Spatial Analyses (i.e., spatial processing and reasoning), and Picture Arrangement (i.e., visual reasoning).

The fourth step of analyses was to conduct ANOVAs on the MicroCog neuropsychological test for each of the first-, second-, and third-level index scores. Subsequent Dunnett's post-hoc tests were completed after each statistically significant ANOVA test to identify where statistically significant between group differences occurred. Additionally, Cohen's *d* effect sizes were calculated for each statistically significant post-hoc comparison to evaluate the magnitude of the difference in group scores.

See Table 8 for the results of analyses assessing between group differences on the MicroCog. Nonrated pilot training candidates who passed RFS, when compared with those who failed RFS, scored higher on the MicroCog in regards to (a) first-level index of

Reasoning/Calculation, (b) second-level index of Information Processing Accuracy, and (c) third-level index of General Cognitive Functioning. Although there were statistically significant differences between such groups on the measures of Attention/Concentration, Reaction Time, and General Cognitive Proficiency, such differences were dismissed at this time because the analyses had less than optimal power.

Nonrated pilot training candidates who passed RFS, when compared with rated pilots who cross-trained, scored higher on the MicroCog in regards to (a) first-level index of Spatial Processing and (b) third-level indices of General Cognitive Functioning and General Cognitive Proficiency. Although there were statistically significant differences between such groups on a measure of Information Processing Accuracy, such differences were dismissed because the analyses had less than optimal power.

4.4 Discriminant Analysis (DA) of Cognitive Aptitudes Contributing to Training Outcomes Among Nonrated Pilot Training Candidates

4.4.1 Predictive Model Development. The test data from nonrated pilot training candidates were analyzed initially using several statistical methodologies to determine which variables provided the best predictive accuracies for success and failure between nonrated pilot training candidates while minimizing both false positive and false negative model outcome rates. The effect of sample size is critical in performing DA. The literature suggests that a minimum of 20-30 records per variable in the model is required. If the number of variables exceeds the sample size requirement, then there is the potential for overfitting the model and subsequent artificial elevation of classification accuracies. Additionally, if the smaller sample to larger sample ratio exceeds 1.5, then larger samples are required. Since the ratio of pass to fail is 2.1 (108/52), then we are limited to 30 samples per variable entered into the model. We have 10 MAB subtests, 5 MicroCog first-level indices, 2 MicroCog second-level indices, and 2 MicroCog third-level indices totaling 19 potential predictors to be considered for entrance into the model. Hence, model development is limited to between 5 (160/30) and 8 (160/20) predictors.

Canonical DA was conducted from which the standardized canonical coefficients were assessed to determine viability of variable inclusion into the model. The interpretation of standardized canonical coefficients is similar to regression coefficients. The canonical correlation for this proposed discriminant model using the development dataset is .299, and Wilks' lambda is .911. These results indicate that this model would likely provide a reasonable amount of predictability. The variables were then submitted to a stepwise DA to determine which variables offered the best predictive accuracy.

Those variables identified using stepwise procedures were then analyzed using standard DA to establish the discriminant function coefficients. This analysis identifies the weighting of each variable according to its relative contribution to the prediction model. Several factors influence the choice of using either a linear or quadratic function in building the model. While DA is not negatively influenced by departures from equal variances, the resultant unequal group sample sizes require that if the variances are not equal, the quadratic functions should be used in this case. However, Table 9 below identifies those linear discriminant function coefficients for the variables included in the DA model. Linear functions were identified resulting from the equality of variances among the model variables. The resulting coefficients have both positive and negative signs. It is important that DA coefficient signs are not interpreted in the same manner as regression coefficients.

Table 7. Between Group ANOVAs and Post-Hoc Dunnett Tests for the MAB-II

MAB-II Subscales & Indices	ANOVA Tests of Between Subjects Effects										Dunnett Post-Hoc Tests									
	ANOVA Tests of Between Subjects Effects					Nonrated Training Candidates Who Passed (n=108) vs. Rated Pilots Who Cross-Trained (n=157)					Nonrated Training Candidates Who Passed (n=108) vs. Nonrated Training Candidates Who Failed (n=52)									
	F test	p-value	Partial eta squared ^a	Power	Mean Difference	p-value	d ^b	Power	Mean Difference	p-value	d ^b	Power	Mean Difference	p-value	d ^b	Power				
Verbal Intelligence Subscales																				
Information	10.31	.00	.06	.99	-1.55 ^c	.05	.28	2.46 ^c	.02	.41	.67									
Comprehension	4.68	.01	.03	.78	-0.35	.72	N/A	1.58 ^c	.03	.42	.69									
Arithmetic	1.57	.21	.01	.33	0.64	.71	N/A	2.10	.13	N/A	.47									
Similarities	1.99	.14	.01	.41	-0.65	.41	N/A	0.69	.51	N/A	.14									
Vocabulary	4.21	.02	.03	.74	-2.01 ^c	.03	.30	0.44	.87	N/A	.07									
Visual-Performance Intelligence Subscales																				
Digit Symbol	0.92	.40	.01	.21	1.06	.36	N/A	1.14	.46	N/A	.18									
Picture Completion	1.20	.30	.01	.26	0.13	.98	N/A	1.57	.23	N/A	.31									
Spatial Analyses	9.21	.00	.06	.98	3.16 ^d	.00	.50	3.18 ^d	.01	.55	.90									
Picture Arrangement	5.78	.00	.04	.87	3.22 ^d	.01	.39	3.74 ^d	.02	.42	.70									
Object Assembly	5.00	.01	.03	.81	1.05	.20	N/A	2.77 ^b	.00	.49	.82									
Indices																				
Full Scale IQ	7.05	.00	.04	.93	1.25	.20	N/A	3.96 ^d	.00	.63	.96									
Verbal IQ	7.15	.00	.04	.93	-1.29	.16	N/A	2.30 ^c	.04	.38	.60									
Performance IQ	8.82	.00	.05	.97	3.75 ^d	.00	.45	4.98 ^d	.00	.59	.94									

^aEta squared effect sizes: small = .01 to .05, medium = .06 to .13, large = .14 or greater.

^bCohen's *d* effect sizes: small = .20 to .49, moderate = .50 to .79, large = .80 or greater (19).

^cIdentifies scores that are statistically significant but cannot be considered meaningful because of less than adequate power.

^dIdentifies group scores that are considered to be meaningfully different based upon a medium with significant post-hoc between group differences with a Cohen's *d* effect size of .40 or larger and power of .70 or larger.

Table 8. Between Group ANOVAs and Post-Hoc Dunnett Tests for the MicroCog

MicroCog Indices	ANOVA Tests of Between Subjects Effects			Dunnett Post-Hoc Tests								
	F test	p-value	Partial eta squared ^a	Nonrated Training Candidates Who Passed (n=108) vs. Rated Pilots Who Cross-Trained (n=157)			Nonrated Training Candidates Who Passed (n=108) vs. Nonrated Training Candidates Who Failed (n=52)					
				Mean Difference	p-value	d ^b	Power	Mean Difference	p-value	d ^b	Power	
				1st-Level Indices								
Spatial Processing	6.43	.00	.04	.90	4.63 ^c	.00	.45	.95	2.76	.18	N/A	.34
Attention/Mental Control	2.64	.07	.02	.52	1.98	.33	N/A	.27	4.55 ^d	.04	.39	.64
Reasoning/Calculation	4.18	.02	.03	.73	2.65	.16	N/A	.43	5.85 ^c	.01	.48	.81
Memory	1.07	.35	.01	.24	0.92	.83	N/A	.08	3.38	.23	N/A	.31
Reaction Time	2.80	.06	.02	.55	2.55	.20	N/A	.36	4.83 ^d	.04	.41	.66
				2nd-Level Indices								
Processing Speed	1.96	.14	.01	.41	2.39	.24	N/A	.33	3.98	.12	N/A	.44
Processing Accuracy	4.16	.02	.03	.73	3.71 ^d	.04	.29	.64	5.39 ^c	.02	.46	.78
				3rd-Level Indices								
General Functioning	14.02	.00	.08	.99	9.57 ^c	.00	.66	.99	7.40 ^c	.01	.51	.85
General Proficiency	4.09	.02	.03	.72	3.28 ^c	.02	.33	.76	3.50 ^d	.07	.37	.59

^aEta squared effect sizes: small = .01 to .05, medium = .06 to .13, large = .14 or greater.
^bCohen's d effect sizes: small = .20 to .49, moderate = .50 to .79, large = .80 or greater (19).
^cIdentifies group scores that are considered to be meaningfully different based upon a medium with significant post-hoc between group differences with a Cohen's d effect size of .40 or larger and power of .70 or larger.
^dIdentifies scores that are statistically significant but cannot be considered meaningful because of less than adequate power.

Table 9. Linear Discriminant Function Coefficients for Variables Influencing Training Outcomes

Cognitive Assessment	Training Outcomes	
	Fail	Pass
Constant	-198.1430	-214.3673
MAB-II Subscales		
Spatial Analyses	0.4310	0.4648
Information	0.9628	1.0547
Vocabulary	-0.3173	-0.4078
Comprehension	3.2196	3.2962
Object Assembly	1.0638	1.1129
MicroCog 1st-Level Indices		
Reasoning and Calculation	0.1996	0.2248
Reaction Time Speed	0.6176	0.6502

Although negative coefficients are generally cause for further interpretation in regression models, such matters are not of concern in DA. The unstandardized discriminant coefficients are the weights used to generate the discriminant score. However, since they do not take into account any differences in the measurement scales of the variable, they are not usually comparable, as in multiple and logistic regression. The standardized discriminant coefficients are comparable, but only in a limited sense. Their rank order, without concern for the positive or negative, provides an indication of the relative contribution made by the variables to the discriminant function. Unlike beta coefficients in multiple regressions, these coefficients cannot be interpreted in rate of change terms, nor do they have associated statistical tests.

Traditional DA procedures do not always evaluate the “interaction” among variables and the myriad of possible relationships among variables. As a result, the next step is to use an eclectic method of entering and removing variables with the best predictive accuracy possible while minimizing group misclassification rates. Unfortunately, the sample size restriction in this study limited this methodology. When determining the number for variables to enter into the model, only those variables with an alpha p-value between .05 and .25 were selected. This resulted in seven variables identified in the stepwise analysis. This would indicate that the use of seven variables may be sufficient for model development and that only minor improvements would be seen using a more eclectic methodology. The resulting predictive accuracies are in Table 10 below.

Table 10. Overall Predictive Accuracies for Initial Model Development

Training Candidates	Classification		Total
	Reject	Accept	
Fail	33 out of 52 63% (correctly rejected)	19 out of 52 37% (incorrectly accepted)	52
Pass	32 out of 108 30% (incorrectly rejected)	76 out of 108 70% (correctly accepted)	108

Table 10 reflects the overall model predictive accuracies. These accuracies are predicated on each candidate, prior to training, having a 50% chance of passing. Thus, any nonrated pilot training candidate with a 50% probability of success would be classified a success,

while those below 50% would be classified a failure. The use of the 50% (.5) cutoff criterion is an established industry standard that results in a balanced classification matrix. If the desire is to reduce either the false positive error rate or the false negative error rate, then adjustments in prior classification rates should be considered. It must be kept in mind, however, that any adjustment away from the .5 cutoff criterion may result in an unbalanced increase in either false negative or false positive error rates.

Table 10 reveals the efficacy of the model by indicating it would select out approximately 33 (63%) of those who would have failed training. The misclassification rate is 32 (30%) of those who would have passed training. However, it is important to note that the model accurately classified 76 (70%) of those who passed training. The model, based upon the variables from Table 8, indicates a somewhat unbalanced approach to being sensitive to selecting in those who are likely to pass training while being less accurate in selecting out those who would have trouble and fail training.

The overall efficiency of the model is 80%, which is very high. It would have accepted (or classified) 95 nonrated training candidates as those who would likely pass. Out of the 95 training candidates, a total of 76 passed, which is 80%. This is substantially higher than the current 68% success rate. The recruitment and training expenditures of an RPA training pilot are costly, and the investment AF leadership puts into a recruit who fails training increases such costs, as well as reduces the capability to meet the projected number of fully trained pilots necessary for sustaining operations. It is reasonable to conclude that the 12% increase in success rates based upon improved capabilities to identify nonrated candidates with the cognitive “right stuff” can reduce such costs.

4.4.2 Cross-Validation of Model Development. Cross-validation procedures used in this study are known as “one out classification.” This procedure treats n-1 out of n training observations as a training set. It determines the discriminant functions based upon these n-1 observations and then applies them to classify the one observation that was removed. It does this through all 160 observations. In other words, cross-validation selects out 1 study participant of the sample of 160 and builds the functions on 159, and then tests the 1 observation it removed. It does this through all 160 participants until every participant has been classified by the functions developed from the remaining 159 participants. This method is believed to maximize the unbiased estimate but at the cost of relatively high variances in the error rates. To reduce the error rate estimates, smoothed error-rate estimates were performed in this analysis.

Table 11 reveals the results based upon the cross-validation outcomes. The requirement from the cross-validation table is that the individual classification accuracies along with the overall classification accuracies are within 10% of the initial model development classification matrix. When using a one-out cross-validation method, “shrinkage” in the predictive classification accuracies often results. This is not of concern unless the classification accuracies between the initial model development matrix and the cross-validation matrix are greater than 10%. This 10% criterion is used to establish the stability of the model performance on repeated independent samples. Although not remaining within the 10% criterion is not necessarily deemed a failure of model performance, the 10% criterion is the target for model validation. The results of this analysis indicate that this model will do reasonably well over time regarding prediction accuracy on new samples of nonrated pilot training candidates relative to their probability of success.

Table 11. Overall Predictive Accuracies for Cross-Validation Model

Training Candidates	Classification Accuracy		Total
	Reject	Accept	
Fail	31 out of 52	21 out of 52	52
	60% (correctly rejected)	40% (incorrectly accepted)	
Pass	35 out of 108	73 out of 108	108
	32% (incorrectly rejected)	68% (correctly accepted)	
Total	66 out of 160	94 out of 160	160
	41%	59%	

5.0 DISCUSSION

The first objective of this study was to obtain normative intelligence data on nonrated RPA pilot training candidates and to assess how such data differ from the civilian, nonaircrew general population.

Overall, the results of comprehensive computer-based intelligence testing with the MAB-II revealed the general intellectual functioning of nonrated pilot training candidates to be in the high average to superior range of functioning when compared with peers of similar age in the general population.

The nonrated pilot training candidates recruited and selected for MQ-1 Predator training performed notably higher on all verbal and visual-performance based subscales of the MAB-II. In addition, nonrated training candidates, as a group, demonstrated particular strengths on the MAB-II and MicroCog in the areas of (a) visual learning and memory, (b) visual construction and perceptual analyses, (c) spatial perceptual aptitude for visualizing and mentally rotating two-dimensional images of objects in different positions, (d) visual memory for novel spatial arrangements, and (e) general memory for visually oriented information. The findings of the study reveal that recruiting and selection processes of the USAF are identifying training candidates, in general, with high levels of cognitive functioning in visual-performance based measure reasonably perceived as critical to adapting to the demands of pilot training.

Furthermore, the results of the study revealed the neuropsychological and intelligence test scores had significantly less variance regarding the distribution of scores when compared with age-corrected (and/or education-corrected) normative general population scores. Simply put, the scores among nonrated pilot training candidates were more homogenous with a much smaller range when compared with the distribution and range of scores for peers in the general population.

5.1 Nonrated Training Candidates Who Passed vs. Those Who Failed RFS Training

The second objective of this study was to assess for differences between nonrated pilot training candidates who passed vs. nonrated pilot training candidates who failed the RFS course.

The results of the study assessing between group differences on computer-based intelligence and neuropsychological testing revealed nonrated training candidates who passed the RFS course had higher scores on measures assessing spatial analyses/reasoning; memory for novel spatial arrangements; general visual reasoning; and visual construction, general executive reasoning, and general information processing accuracy. These areas of cognitive functioning are reasonably perceived as critical to pilot training, especially under high-risk, high-demand conditions.

Although measures of cognitive proficiency (combination of speed and accuracy of information processing), attention/concentration, and reaction time were significant, the statistical analyses had less than adequate power. However, it is important not to dismiss such differences. It is highly likely that by increasing the sample size for the nonrated pilot training candidates who failed, the power for assessing comparisons will increase and subsequently raise the confidence in the findings for such between group differences.

The results of this study provide empirical support to previously published qualitative studies regarding cognitive attributes considered relevant to adapting to the demands of RPA pilot duties (Bailey M, *Predator Pilot and Sensor Operator Selection Test Batteries*, Royal Air Force Technical Report, Cranwell Royal Air Force Base, England, 2009; available by request only) (1). The results of previous studies regarding USAF MQ-1 Predator pilots found perceptual reasoning and processing, short-term memory, spatial reasoning, speed and accuracy of information processing (i.e., cognitive proficiency), psychomotor dexterity, and reaction time to be cognitive aptitudes that distinguish RPA pilots from the general population. The data from this study show the nonrated pilot candidates who passed training performed better in these same domains in comparison with the group who failed training.

Although the nonrated pilots who passed RPA training outperformed those who failed training on the cognitive aptitudes listed above, it is important to note those who failed training also performed in the high average to superior range on the computer-based intelligence testing. This finding suggests that having a high level of general intellectual functioning is necessary but not sufficient for success in RPA pilot training. A more useful approach may be to go beyond general intellectual ability and identify specific types of cognitive aptitudes that are associated with success in RPA training and operations.

5.2 Variables Predictive of Pass vs. Fail Performance Outcomes Among Nonrated Pilot Training Candidates

As mentioned previously, the traditional selection and classification process for nonrated direct-accession RPA pilot training applicants is based upon generic cutoff scores for tests of cognitive aptitude. Although there are differences in cognitive aptitude between those who pass vs. fail training, there is a lack of empirical data regarding the type of aptitudes most predictive of outcomes. As a result, DA procedures were utilized to develop a comprehensive model based upon variables with predictive influence on training (pass/fail) outcome scores.

The results of DA found a combination of measures regarding spatial analyses and reasoning, visual construction and reasoning, psychomotor reaction time, general reasoning and calculation, as well as general fund of knowledge and social reasoning/comprehension to identify (with a reasonable degree of accuracy) the suitability of a nonrated training candidate for the RFS portion of RPA pilot training. It is important to note there is a range of differences on measures of cognitive aptitude between training candidates who fail vs. pass

training. However, a review of the effect sizes reveals the magnitude of differences ranges from small to large, and not all of the between group differences are predictive of training outcomes. Nonetheless, the result of DA reveals that a more specific cognitive aptitude model combining verbal and visual-performance based aptitudes may improve the classification process for nonrated pilot training candidates.

By developing an overall adaptability rating using DA, it is possible to improve the capabilities for identifying those candidates at high risk for performance problems and those likely to adapt and succeed during RFS. The model, based upon the variables from Table 8, would likely result in an overall efficiency of approximately 80%, which is substantially higher than the current 68% success rate.

The recruitment and training expenditures of an RPA training pilot are costly. The investment AF leadership puts into a recruit who fails training increases such costs, as well as reduces the capability to meet the projected number of fully training pilots necessary for sustaining operations. It is reasonable to conclude that the 12% increase in success rates based upon improved capabilities to identify no-rated candidates with the cognitive “right stuff” can reduce such costs. The model may also be potentially used to refine the classification process of recruits as well as class size for training candidates. The reduction in class size may enable training instructors to invest more time and focus on training of qualified recruits rather than having to identify and eliminate the candidates who are unqualified and/or unsuitable.

5.3 Nonrated Pilot Training Candidates Who Passed RPA Training vs. Rated Pilot Training Candidates Who Cross-Trained

The third objective of this study was to assess for differences between nonrated pilot training candidates who passed RPA training vs. rated pilot training candidates who cross-trained from a manned airframe.

The results of the study suggest that in terms of general intellectual functioning and visual-performance based aptitudes, nonrated pilots who passed the RFS course of RPA pilot training have similar levels of intelligence and cognitive aptitude when compared with rated USAF pilots from manned airframes (5,6,8,10).

Furthermore, when compared with rated pilots who cross-trained, as a group, nonrated pilot training candidates who passed the RFS course performed higher on computer-based intelligence and neuropsychological test measures assessing spatial analyses/reasoning, memory for novel spatial arrangements, visual reasoning, general information processing accuracy, and cognitive proficiency (a combination and accuracy of speed of information processing). Such computer-based, visual-performance aptitudes are reasonably perceived as critical to effectively piloting a sophisticated weapons-bearing RPA aircraft. The results of this study provide empirical support to the qualitative results of a previously published study (1) on the aptitudes perceived as critical to successful MQ-1 Predator pilots.

Overall, the results of computer-based intelligence and neuropsychological testing reveal nonrated pilot training candidates who passed the RFS course are as intelligent and cognitively capable as those rated to fly manned airframes and that the group of nonrated pilot candidates who passed the RFS course are motivated to become RPA pilots with particular strengths in visual-performance based aptitudes.

5.4 Aeromedical Implications

Understanding the normative distributions of various cognitive aptitudes and intelligence tests in RPA pilots from nonrated accession sources has significant implications in the aerospace medicine arena. For psychologists and psychiatrists to make fair and accurate assessments when conducting aeromedical evaluations on this population, they must understand the cognitive aptitudes and abilities required for adapting to the demands of this unique RPA pilot career field.

The current data suggest that nonrated MQ-1 Predator pilot training candidates who pass training tend to score in the high average to superior range on measures of general intellectual ability and cognitive aptitude. This finding is consistent with prior data collected on rated USAF pilots that suggest the most appropriate normative data group for RPA pilots in terms of general intellectual functioning and cognitive aptitude is rated USAF pilots and not the general civilian population. For example, a pilot training candidate with an MAB-II score of 106 would be considered to be within normal limits for the general population. However, when compared to USAF rated pilots, this score would be considered to be well below normal limits (at or below the 10th percentile) and would raise significant concerns about the person's cognitive capability to respond to the high-demand, high-risk nature of the MQ-1 Predator training and operational environment.

The results of the study also provide additional support to current USAF aeromedical policy regarding RPA pilot standards for training candidates and incumbents. Any sort of developmental, academic, or learning problems as well as medical and psychiatric illnesses that affect performance and that may affect cognitive functioning are disqualifying for RPA pilot duties. Flight medicine physicians must ensure that RPA pilots or pilot training candidates have fully recovered from any sort of illness or injury that has the potential for negatively affecting general cognitive functioning before clearing them for RPA duties and/or training. This would also include any sort of closed head injuries or neuro-ophthamological conditions that increase seizures risks or other issues that may raise concerns about reliability of performance during cognitively high demanding operations.

The current study also provides preliminary evidence that beyond high levels of general cognitive and intellectual ability, visual-performance based aptitudes and cognitive proficiency are associated with successful performance in the MQ-1 Predator (or similar RPA platform) environment. The results of this study suggest that flight medicine providers evaluating RPA pilots or trainees should consider computer-based tests assessing capabilities in spatial analyses and reasoning, visual construction, visual reasoning, attention/concentration, general executive reasoning, as well as speed and accuracy of information processing. Future research to confirm and specify the association between RPA pilot performance and these aptitudes not only will help aeromedical personnel in the evaluation processing but may also be used to improve the selection criteria employed by USAF recruiting agencies to identify young adults suitable for this profession.

5.5 Limitations of the Study

Although this study used a large sample of RPA pilot training candidates with reliable and valid measures of cognitive functioning, there are notable limitations to the study. First, additional studies are needed regarding predictive model development and establishment of cognitive aptitude test scores clearly predictive of performance problems and pass/fail training

outcomes. Second, generalizing the results of this study to other RPA pilot career fields across military branches is likely not appropriate. The classification process, type of operational missions, and requirements differ significantly between RPA missions and airframes across branches of the Armed Forces. Third, repeated studies are needed to assess for differences regarding minority group status. Studies evaluating cognitive performance should remain sensitive to differences between minority groups to ensure objective and unbiased decision-making within the aeromedical community. Fourth, the study did not account for motivation (i.e., the inherent interest in the RPA pilot career field), which may influence training performance outcomes. It is reasonable to perceive that high levels of motivation, and drive to succeed in the RPA pilot career field specifically, may help to explain differences between nonrated pilot training candidates who passed vs. those who failed. Fifth, awareness of unpredictable life events (e.g., marital problems, death of a loved one) that may have interfered with performance and resulted in failure of those who would have otherwise passed would also be helpful to know. It is possible that unforeseen life circumstances and additional life stressors had a role in performance outcomes among those who failed, but under more optimal conditions would have passed. Lastly, this study did not include personality testing (aspects of a person's emotional and interpersonal disposition that remain constant despite fluctuations and changes in one's surroundings). It is evident from previous research that personality is considered to have a key role in adaptation to training demands and rigors (1). The inclusion of personality testing that is predictive of pass vs. fail training outcomes may improve the incremental validity of cognitive aptitude testing and significantly aid in the aeromedical evaluation processes assessing training candidates' suitability to fly.

6.0 CONCLUSIONS

Appropriate normative data are critical to the accurate and effective interpretation of intelligence test scores that are often a part of the aeromedical evaluation process to determine a person's suitability for participating in high-risk, high-demand, high-precision aviation-related duties. The results of this study indicate that successful RPA pilots score in the high average to superior range of functioning in terms of general intelligence and cognitive aptitude and support the use of USAF rated pilot normative data over general civilian population normative data when evaluating RPA pilots or trainees. Additionally, superior performance in specific cognitive aptitudes was also found in successful RPA pilot trainees, providing preliminary evidence that visual-performance based aptitudes and cognitive proficiency may be uniquely associated with success in the RPA environment. Furthermore, the results of the study suggest that a combination of verbal and visual-performance based cognitive measures may be combined to develop an overall adaptability rating that predicts the general suitability of a young adult for MQ-1 Predator pilot duties. This would improve current classification as well as aeromedical evaluation processes.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACC	Air Combat Command
ANOVA	analysis of variance
CAS	close air support
DA	discriminant analysis
FSIQ	full-scale intelligence quotient
FTU	Formal Training Unit
ISR	intelligence, surveillance, reconnaissance
MAB-II	Multiple Aptitude Battery-II
MR	Mission Ready
PIQ	performance intelligence quotient
RAF	Royal Air Force
RFC	RPA Fundamentals Course
RFS	RPA flight screening
RIQ	RPA Instrument Qualification
RPA	remotely piloted aircraft
SD	standard deviation
SME	subject matter expert
SUPT	Specialized Undergraduate Pilot Training
UK	United Kingdom
USAF	U.S. Air Force
VIQ	verbal intelligence quotient