CAN SITUATION AWARENESS BE PREDICTED?
INVESTIGATING RELATIONSHIPS BETWEEN COGSCREEN - AE
AND
PILOT SITUATION AWARENESS

by

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Abstract

This two-phase study assessed CogScreen – Aerospace Edition (AE) as a potential predictor of situation awareness. It included a cognitive task analysis and empirical testing. Sea King pilots completed the CogScreen – AE and a situation awareness task (a simulated deck landing tasks using the Helicopter Maritime Environmental Trainer). The Situation Awareness Global Assessment Technique was used to assess participants' situation awareness. The situation awareness task revealed experienced pilots to be more accurate and more confident than inexperienced pilots. Probes tapping into comprehension of the situation resulted in the highest accuracy. The higher situation awareness performance group included some inexperienced pilots. This group demonstrated better accuracy on two CogScreen – AE tests. These results demonstrate a predictive relationship with situation awareness in terms of recall, retention; working memory, attribute identification and motor tracking.

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Can Situation Awareness be Predicted?

Investigating Relationships between CogScreen – AE and Situation Awareness

This study aimed to answer the following research question: Can an off-the-shelf test such as the CogScreen – AE predict situation awareness in pilots and become part of their selection process? It was hypothesized that if the CogScreen – AE is a valid predictor of situation awareness, then the CogScreen – AE scores would have a positive relationship with simulator situation awareness scores. It was also hypothesized that inexperienced pilots who scored high on the situation awareness simulated scenarios would also score high on the CogScreen – AE test.

This thesis starts with a background on situation awareness including definitions, components, measures, and related studies particularly those focusing on individual differences. The importance of situation awareness in the aviation context is discussed next, in addition to a review of current pilot selection tests. The background section also reviews CogScreen – AE, its sub-tests and constructs reliability, validity, and related research studies. An analytic match between CogScreen – AE sub-test components and situation awareness constructs demonstrate why this test battery can be considered suitable to assess situation awareness as part of pilot selection testing.

This study was conducted in two phases. Phase 1: Cognitive task analysis; and Phase 2: Empirical testing. These phases involved rotary wing CH - 124 Sea King pilots as subject matter experts (SMEs) and as test participants. The task involved simulated CH – 124 Sea King deck landings using the Helicopter Maritime Environmental Trainer

(HelMET). The cognitive task analysis uncovered several situation awareness constructs involved in this task: perception, attention, memory, spatial cognition, and other cognitive functions, which are well established in the situation awareness literature. Based on this analysis, situation awareness probes were created for each deck landing scenario, reflecting three levels of situation awareness involved at each critical way point or event. Related CogScreen – AE sub-tests were also noted for each identified construct.

The empirical phase involved inexperienced and experienced pilots running three simulated deck-landing scenarios and performing the CogScreen – AE tests. Situation awareness accuracy scores and response confidence ratings were analyzed as a function of experience level (inexperienced versus experienced pilots). The experienced pilots were significantly more accurate and more confident than the inexperienced pilots. Responses to level 2 situation awareness probes resulted in the highest accuracy for both experience levels. Mean situation awareness accuracy scores and mean confidence ratings showed a positive relationship for the inexperienced pilots. CogScreen – AE accuracy and throughput scores were analyzed as a function of both experience level and situation awareness performance groups. There were no significant differences between the experience group's accuracy with one exception; the Dual Task Tracking (DTT) test. The inexperienced pilots approached significance in comparison to the experienced pilots on the Dual Task Tracking (DTT) Previous number alone test than when it was combined with motor tracking in the dual task condition. The inexperienced pilots were significantly more efficient than their counterparts in learning symbols-digit pairings, and in identifying attributes; evident from their Symbol Digit throughput scores and their Shifting

Attention Test – Arrow color throughput scores. The high situation awareness performance group was significantly more accurate than the low situation awareness performance group on the Dual Task Tracking previous number alone task and the Symbol Digit Coding immediate and delayed recall and retention tests. In addition to motor tracking skills, these sub-tests tap into memory; a key component of situation awareness. More specifically these tests assess: recall, retention; working memory, attribute identification.

Background

Defining Situation Awareness

The objective of this study was to assess the feasibility of a commercial cognitive test to be used in pilot selection to test situation awareness ability. This objective necessitates a clear working definition of situation awareness. Aviation, like other domains such as medicine (Gaba, Howard, & Small, 1995), battlefield management (Kass, Herschler, & Companion, 1991), and nuclear power plant systems, rely on situation awareness for successful operations (Endsley, 2000). Despite its applicability across several domains, the term, situation awareness, remains ill-defined. In aviation, pilots, air traffic controllers, uninhabited aircraft vehicles (UAV) operators and their respective instructors, intuitively speak of assessing situation awareness without being able to clearly define it. Given the aviation context of this study, the review on situation awareness will be limited to this domain.

According to Uhlarik and Comerford (2002), situation awareness involves the operation and control of complicated systems in dynamic environments in which the operator has to rely on visual, auditory, tactile and vestibular inputs to fully understand

their moment-by-moment environment. This definition limits situation awareness to sensory, perceptual inputs and comprehension of these inputs. It does not account for projecting future actions based on such perceptions and comprehension. Endsley (1988, p. 792), is most often cited for her definition of situation awareness, “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future” which is based on an information-processing model (Uhlarik & Comerford, 2002) and includes perception, memory, schemata to make decisions and perform tasks (Matthews, Beal, & Pleban, 2002). Endsley (1999) further purports that situation awareness consists of three hierarchical phases, Level 1: perception of the elements in the environment; Level 2: comprehension of the current situation; Level 3: projection of future status. Level 3 projection however is not well defined.

One might argue that projection is decision-making or that an executed decision is the product of the process. Endsley (2000) partially agrees with Adams, Tenney, and Pew (1995), and Smith and Hancock (1995), that there is an integral relationship between situation awareness and decision-making but she claims that decision-making occurs after level 3 projection. As noted by Shanmugaratnam and Parush (2009), Carroll’s definition goes one step further than Endsley’s (1988) to include execution of tasks (decision-making); not only the lead up to execution. This definition includes both the process and product and is described as “the pilot’s continuous perception of self and aircraft in relation to the dynamic environment of flights, threats, and mission, and is the ability to forecast, then execute tasks based on that perception” (Carroll, 1992, p.5). Wickens

(1992) suggests that situation awareness affords mental access to relevant information about an evolving situation. In a sense, this refers to efficiency information acquisition.

Some researchers (Adams, Tenney, & Pew, 1995; Smith & Hancock, 1995) support a perceptual-action cycle approach. Smith and Hancock (1995, p. 138) define situation awareness as “adaptive, externally directed consciousness in which the operator uses both knowledge and behaviour to achieve goals given the current circumstances and environment”. Flach (1995) disputes situation awareness being behaviourally-related and suggests that it is more of a descriptive label. He regards its usefulness merely in categorizing events rather than as an intervening or explanatory variable. Flach has been criticized for this approach, calling into question whether the term is needed at all if it only provides categorical labeling (Shanmugaratnam & Parush, 2009).

Durso, Rawson, and Giroto (2007) prefer the term situation comprehension to situation awareness. They describe it as a system of cognitive processes that operates at three basic levels: surface level, text base and situation model (Kintsch, 1998). Others prefer situation assessment rather than situation awareness (Federico, 1995; Fracker 1988; Wickens, Gordon, & Liu 1998). This premise is based on clusters of knowledge that are schemata-driven processing that allow the pilot to categorize events (Uhlarik & Comerford, 2002). This approach however is ambiguous without schemata being well defined or elaborated upon.

It is evident from the review above that several situation awareness definitions exist. Despite the ambiguity in defining situation awareness, job analyses for the pilot occupation have typically suggested that situation awareness is an important and relevant

attribute even without the ability to describe it or its underlying abilities or constructs. For this study, Endsley's (1988) definition was chosen as the working definition, given its three hierarchical levels of situation awareness which aided in classifying scenario events during the cognitive task analysis and provided insight during data analysis on situation awareness levels at work.

Importance of Situation Awareness in Pilot Selection

Pilot situation awareness errors have been found to be the leading cause of military aviation mishaps (Hartel, Smith, & Prince, 1991; Endsley & Robertson, 2000).

Of the 72% human error-related accidents (Endsley, 1995b), 88% of them were attributed to situation awareness problems as opposed to decision-making or flight skill problems (also Jones & Endsley, 2000). The majority was Level 1 perception errors, ranging from 72-76% and was due to data unavailability, data difficulties, data misperceptions, observation failures, and memory loss. Level 2 comprehension errors ranged from 20- 22% and included incomplete or incorrect mental models and over-reliance on default values. Level 3 projection errors represented only 3-6% of all situation awareness errors and included incomplete or poor mental models, and over-projection of current trends. High percentages of situation awareness errors indicate that current methods of training situation awareness in pilots are insufficient and suggest that improvements must be made. The question is whether or not such improvements can also be addressed through pilot selection. Although the aforementioned studies are rather dated, they exemplify that pilots will err regardless of their experience level. Therefore, if candidates can demonstrate superior situation awareness abilities in selection, and can be

distinguished from those who cannot, then screening for situation awareness could result in enhanced pilot performance. In such a case, selection of individuals with high situation awareness should be considered.

Until now, situation awareness has been routinely introduced through Air Force pilot training (confirmed with subject matter experts during the phase 1 Cognitive task analysis). Nonetheless, Endsley (2000) found that novice aircrew and those in novel situations were particularly challenged by limitations of human attention and working memory, having less capacity to process or acquire new incoming information. Endsley also supported the idea that situation awareness (particularly level 3 - mental projection) was synonymous with expert-level performance; something that is inherently gained through time, exposure and experience (Crane, 1992). However, in Endsley's aforementioned studies of accidents and situation awareness errors, few level 2 or level 3 errors were reported. This suggests that even experienced pilots may not be working at level 3 or, are not making errors at the higher levels, but rather mostly at level 1 (e.g., failing to perceive cues). If situation awareness had been screened in selection, pilots making the situation awareness-related errors may not have been selected and perhaps accidents could have been prevented.

Although common situation awareness training exists and pilot candidates are given the similar number of training hours, anecdotal evidence suggests that there is a considerable amount of variance between pilots at the performance (skill) level, with a portion of that variance related to individual differences in situation awareness (Youngling, Levine, Mocharnuk, & Weston, 1976). Endsley and Bolstad (1994) found

support for this claim in their study in which experienced fighter pilots' scores on a situation awareness - related test battery were compared to their mean situation awareness scores (based on SAGAT probes for an air-to-air engagement in a multi-engagement simulator). Their results indicated that some individuals have higher situation awareness than others particularly in spatial and perceptual skills. They also found that these individual differences are fairly consistent within individuals. For this reason, situation awareness testing in selection could play a major part in identifying those who possess strong situation awareness. Although a small sample of experienced pilots was used (not uncommon in aviation studies), the results suggested that individual situation awareness differences do exist.

Taken together, previous work indicates a strong need for a situation awareness pilot selection test. In addition, studies show that there are individual differences (and this will be reviewed further later) implying that a valid test can distinguish between individuals based on their situation awareness abilities. As is the case with any selection test, there is a need to identify the components and constructs underlying the tested ability.

Situation Awareness Constructs

The following is a review of some of the components and constructs of situation awareness identified by previous research. Carretta, Perry and Ree, (1996) conducted a U.S. Air Force study with 171 active duty fighter pilots and found that flying experience, measured in F-15 hours, was the best predictor of situation awareness. After controlling for the effects of F-15 flying hours, the measures of general cognitive ability based on

working memory, spatial reasoning, and divided attention were found to be predictive of situation awareness. Psychomotor and personality measures were not predictive.

Conversely, Endsley and Bolstad (1994) found some positive results for psychomotor skills. Individuals who were able to perform difficult tracking tasks had higher situation awareness than individuals who were able to perform easier tracking tests. Their results suggest that better proficiency in tracking elements allows more focus to other stimuli in the dynamic environment.

Other researchers have identified other underlying components of situation awareness in their research. For instance, Harwood, Barnett, and Wickens (1988) suggested that situation awareness might consist of spatial awareness, identity awareness and temporal awareness (Uhlarik & Comerford, 2002). O'Hare (1997) found elite pilots performed better on divided attention tasks and Gugerty and Tirre (1997) found that people with better situation awareness performed better on measures of time-sharing ability, temporal processing, visual processing and working memory.

Endsley and Bolstad (1994) identified five key areas that may relate to individual differences in situation awareness: spatial cognition, attention, memory, perception and cognitive functions including cognitive complexity, field independence, locus of control and compulsiveness/decisiveness. Studies involving these constructs are listed below.

Spatial Cognition

The flight environment requires an understanding of spatial relationships between dynamic objects in three-dimensional space. Navigation also requires the ability to possess a mental map of the environment. In addition to these claims, Endsley and

Bolstad (1994) found that spatial orientation skills (an aspect of spatial cognition) are important for situation awareness but are not generally trainable. This lends support for spatial cognition's inclusion in pilot selection batteries. To date, this aspect has been addressed in several pilot selection tests including that of Lufthansa airline, the U.S. Air Force Basic Attributes Test (BAT), (Carretta, 1987; Kantor & Bordelow, 1985); and the Canadian Forces Aptitude Test (CFAT) (Boswell & Kuschnereit, 2009).

Attention

Attention relates to task management (i.e. noticing what needs attention (level 1 situation awareness), understanding the cue in relation to other conflicting priorities (level 2 situation awareness), and projecting its relevance in the near future (level 3 situation awareness). Endsley and Bolstad (1994) recognized several studies of attention capability that found correlations between time-sharing (selective attention) capabilities during training (Damos, 1978; Damos & Wickens, 1980; also Endsley & Bolstad, 1994) and in flight performance (Damos, 1978; Gopher & Kahneman, 1971; also North & Gopher, 1976). Studies comparing better and poorer performing pilots indicated that better multi-tasking performance resulted from rapid switching abilities between tasks (Wickens, 1999). Wickens suggested that attention-management strategies, such as checklists, foster routine performance and can actually narrow focus on parameters of flight control and potential hazards. Therefore, they do not support situation awareness enhancement (Wickens, 2002). This exemplifies why some situation awareness problems may be better resolved through improved selection rather than training.

Memory

Situation awareness involves cognition and working memory, is relevant to dynamic evolving situations and is therefore not the same as static knowledge of long-term memory mental models (Adams et al., 1995). Attending to some events and filtering out others is dependent upon working memory. Higher situation awareness levels (comprehension of perceptions, and projection of future events) call upon working memory as pilots integrate information from multiple sources, compare this information to their objectives and project future scenarios from known dynamics and information. Working memory is further plagued by concurrent decision making and other flight monitoring tasks and communication protocols (Endsley & Bolstad, 1994). With experience, long-term memory stores may reduce working memory loads as they build up common schema into mental models over time. Endsley and Bolstad (1994) studied the relationship between memory and situation awareness, however their immediate and delayed memory tests did not provide support of such a relationship.

Given the premise that experience may enhance situation awareness by reducing the amount of mental resources required to build and to maintain situation awareness, Sohn and Doane (2004) examined the role that memory processes had on situation awareness, as a function of pilot expertise. Their research objective was to devise and compare measures of both working memory capacity and long-term memory skill in their ability to predict performance differences on situation awareness tasks. Working memory capacity was more predictive of performance in novices whereas long-term memory skill was more predictive of expert pilot performance. This is consistent with

the prediction of skill acquisition theories, whereby general cognitive ability plays a greater role in the initial stages of learning than do practiced skills (Ackerman, 1988; Sohn & Doane, 2004).

Perception

As noted by Shanmugaratnam and Parush (2009), those who perceived displays for a brief time had better situation awareness than displays presented for a long duration (Endsley & Bolstad, 1994). Perceptual encoding results were also analyzed, finding a moderately good correlation ($r = -.55$) for reaction time on tests and situation awareness levels. Those who responded quicker on the encoding test had higher situation awareness than those who responded slowly. Vigilance sub-tests did not reveal any substantial correlations with situation awareness but this may have been due to the nature of simulation task in the study where vigilance may not have been measured.

Cognitive Functions

Thorndyke and Stasz (1980) investigated knowledge acquisition procedures in map learning and found differences between participants. All subjects were initially taught effective learning strategies but in later experiments, only good learners continued to use and apply these strategies, paying attention to unlearned material, encoding spatial information, evaluating progress and remaining work. Poor learners had several difficulties including: attention focus, ineffective procedures, knowledge integration failures, infrequent self-monitoring, non-use of feedback, and learned information feedback interference (they would return to learned information that was comfortable

rather than spend resources on unlearned material). This study supports cognitive testing in selection, showing that not all people have the requisite ability to learn abstract tasks. Given situation awareness' abstract nature, it is very possible that training will not help some people. Selecting those with a superior learning ability in addition to situation awareness abilities could enhance selection of new pilots.

There is some agreement that the spatial component relates to the three-dimensional environment, mapping, mental rotation and field independence, to a lesser extent. Attention includes monitoring, selective attention, divided attention, and switching abilities. Memory relates to attribute identification, working memory, long-term memory (mental models) while perception speaks to visual and temporal processing, identity awareness and temporal awareness. Whereas the components of situation awareness have been enumerated through several studies, the remaining challenge is how to empirically measure these abilities. In the next section, several situation awareness measures are explored.

Situation Awareness Measures

Measurement is one more challenge to researchers interested in situation awareness. Uhlarik and Comerford (2002) provide a comprehensive synopsis of how several researchers (Fracker, 1991; Sarter & Woods, 1995; Vidulich, 1992; Wickens, 1992) delineate situation awareness measures into three measurement categories: (a) explicit, (b) implicit, and (c) subjective. The intent here is not to conduct another comprehensive review, only to briefly highlight the various measurement options.

Explicit Measures

Explicit measures are those that question the subject overtly. These include: retrospective, concurrent and freezing technique measures. Retrospective measures are gauged after the completion of a task whereby the participants recall events or describe decisions made. Concurrent measures, or real-time measures, assess situation awareness during live performance of the task and are particularly useful during operations that cannot be halted or that are too expensive to re-enact for research purposes. Durso's concurrent measure, Situation Present Assessment Method (SPAM) interrupts and asks situation awareness-related probes regarding the current environment through a landline telephone during the task (Durso, Hackworth, Truitt, Crutchfield, & Manning, 1988). The freeze technique is a combination of the retrospective and concurrent measures. The simulation is paused in order to pose questions about the task. The screen and indicators are blanked to ensure no clues or prompts are provided. The Situation Awareness Global Assessment Technique (SAGAT) is a freeze technique that resolves issues of time decay and mental workload. At each freeze point, the pilots are asked questions from a pre-defined bank of task-relevant probes. Endsley, (1995a) found that accuracy was not affected by post-freeze time lapse, and that the task performance was not impeded by the length of each freeze or the number of freezes. She concluded that the SAGAT was unobtrusive, and was not affected by the limits of working memory (Uhlarik & Comerford, 2002). It should be noted however, that SAGAT has been validated for use with experienced operators only; which causes a challenge for predictive validity studies.

Implicit Measures

Implicit measures include external task measures. They are subtle, inferential and unobtrusive since the operator is not aware of measurement taking place (Uhlarik & Comerford, 2002). These measures tend to have high predictive validity since they provide information about participant reactions in real situations without the pressure of time, workload, distraction or assessment. External task measures require extraction of information from a display. Reaction time is recorded, but may not be useful since other stimuli may take priority and result in slower reaction times. Therefore accurate timings may be difficult to capture (Uhlarik & Comerford, 2002).

Subjective Measures

Subjective measures include direct and comparative self-ratings and observer ratings. The Situation Awareness Rating Technique (SART) is an example. It is strictly opinion-based from the participant, the peer or supervisor assessor, or from a Subject Matter Expert (SME) observer using a Likert-type scale. Such measures are survey-based and reflect upon an event or scenario in relation to the subject's perceptions, observations, and understanding in addition to other cues of awareness, such as projected and subsequent actions taken. Self-reporting or observer ratings can raise issues of validity and reliability because of the subjectivity and bias. To better understand application of these measures, the studies below examined how SAGAT, SPAM and SART compared, in finding the right approach for the proposed study.

Comparative Studies of Situation Awareness Measures

Given that much of individual's situation awareness is very subtle, unobtrusive, and often intuitive, makes its measurement a difficult task. Drawing attention to aspects of the task through questioning can often lead the participant, and cause embellishment of responses. Subjective measures make unbiased assessments difficult. Reviewing studies that compare these techniques should prove useful in selecting one for the study at hand.

Venturino, Hamilton, and Dvorchak (1989) used an implicit measure of situation awareness. Participants reporting low situation awareness or medium situation awareness, respectively, had low or medium implicit measure scores. Those reporting high situation awareness had a variety of high and low implicit measure scores indicating performance across all levels. This study suggests that high situation awareness may be necessary but not sufficient to warrant good performance (Uhlarik & Comerford, 2002). However, a high self-reported situation awareness score could also suggest that participants in this category may not be as self-aware as those in the two lower categories with a false sense of abilities or over confidence.

In another study, Endsley, Sollenberger, and Stein (2000) conducted a comparison of SAGAT, SPAM, and SART for use with Air Traffic Controllers (ATC), including both simulation studies and operational setting studies. Endsley et al. (2000) found good sensitivity for the SAGAT measure, but not for the on-line, real-time (SPAM) measure or the subjective (SART) measure. Observer ratings of situation awareness were highly correlated with observer ratings of performance, which again calls into question whether observers are able to separate high situation awareness from high performance. This lack

of independence for subjective situation awareness ratings and performance ratings has previously been criticized (Endsley, 1996). When combined, SPAM and SAGAT measures resulted in interference issues.

Jones and Endsley's (2000) examination also assessed SPAM, SAGAT and SART in addition to two workload measures: NASA-TLX, and response time to a secondary task. There was a weak but significant correlation between real-time SPAM measures and SAGAT measures. All three situation awareness measures (SPAM, SAGAT and SART) showed sensitivity to differences between the two scenarios. The real-time probes and SART showed differences at the overall level while SAGAT showed differences at the individual query level providing diagnostic detail.

Uhlarik and Comerford (2002) acknowledged that competent performance and situation awareness are difficult to reconcile since performance can be effective without the operator having strong situation awareness. Yet aviators often think that strong performance automatically means strong situation awareness and vice versa. This suggests an interesting question: If competent performance or expertise can occur without strong situation awareness, is it possible to have strong situation awareness without first having the competent performance or expertise? This question provides the thrust behind this study. Can situation awareness be measured in pilot selection without the candidate having the expertise of a pilot? More specifically, is there enough variance between individual abilities to separate those that have high situation awareness from those that have little to no situation awareness? This leads to the question of what is known from previous research on individual differences in situation awareness.

Individual Differences in Situation Awareness

Individual differences include experience, training and individual attributes (Endsley & Bolstad, 1994) as well as the ability to respond to task workload, and to moderate the quality of the operator's situation awareness (Endsley, 1988). Flying experience offers several benefits to enhance situation awareness, including the development of episodic memories to draw upon for pattern-matching and solution selection, leading to higher level structured schemata, mental models and enhanced decision-making. Environmental cues can also trigger memories of similar experiences, reducing the workload involved, by reducing attention and attention sharing resources.

Experience develops automaticity for tasks whereas training can assist in developing situation awareness in new pilots and raise their consciousness about the ever-changing and dynamic environment in which they operate (Endsley & Bolstad, 1994). However, given their inexperience, additional resources are required for attention sharing since junior pilots possess limited schemata and mental models that are not always available for reference and retrieval. Levine, Schulman, Brahlek, and Fleishman (1980), looked at the feasibility of training selected abilities to see if they would transfer across tasks and thus reduce training time and increase personnel flexibility. Training did not significantly enhance spatial visualization, as measured by a standard ability test administered before and after training. If selection can target candidates that have innate situation awareness abilities prior to commencing pilot training, then success rates in training can be optimized particularly since transfer of skills does not appear to be trainable, as noted for spatial abilities.

Current Cognitive Tests in Pilot Selection

Dating as far back as World War II (Goeters, Maschke, & Eißeldt, 2004), psychometric selection testing has typically consisted of cognitive ability measures based on results from pilot job analyses. These job analyses have continuously rated cognitive abilities as either ‘relevant’ or ‘very relevant’. Yet these tests have mainly tapped verbal skills, some spatial ability and basic arithmetic reasoning; examples include the U.S. Air Force Officer Qualifying Test (AFOQT), the Basic Attributes Test (BAT) and the Canadian Forces Aptitude Test (CFAT). In addition to the CFAT, the Canadian Forces (CF) incorporates a selection simulator test, namely the Canadian Automated Pilot Selection System (CAPSS) which is a job sample test of complex cognitive skills and psychomotor coordination (Woycheshin, 2002). The Royal Air Force Aircrew Aptitude test (RAFAAT) battery (Southcote, 2004) is a long-standing aviation battery used for pilot selection in the UK and several other countries. In selection, prospective Royal Navy helicopter pilots complete five RAFAAT sub-tests: one measuring spatial visualization, two measuring attention capabilities, and two measuring psychomotor abilities¹.

In a job analysis of airline pilots undertaken in 1977, Goeters et al. (2004) used the Fleishman Job Analysis Survey (F-JAS) to examine the classification of average ratings for 141 pilots. Situation awareness was described as 1 of 19 factors under the category of interactive/social skills. Of all the knowledge, skills and abilities examined, interactive/social skills (cognitive, interactive/social, psychomotor, physical, and sensory)

¹ The Canadian Forces is collecting data on the RAFAAT however no results are available as of yet.

had the highest number of relevant or very relevant factors (77%). On a Likert-type scale ranging from 1 - not at all relevant to 6 - most relevant, situation awareness received a rating of 5 with only stress resistance, cooperation, communication and decision-making receiving a 6 and being considered most relevant.

More recently, during a Canadian Forces (CF) rotary wing (RW) pilot job analysis (Darr, 2010), pilot subject matter experts (SMEs) deemed situation awareness to be necessary and practical. However, less than 75% of surveyed pilot respondents determined that trouble would ensue if situation awareness was ignored in selection, rendering situation awareness as not critical to selection. Their respective operational definitions of situation awareness likely varied, and are not known. Given long-standing pilot situation awareness training, the respondents may have assumed that selecting for situation awareness was not possible or that it would be too difficult to find in the applicant population.

What did manifest as critical competencies (eligibility criteria), not to be ignored in selection were: cognitive capacity, psychomotor ability, communication, thinking skills and conscientiousness. Although situation awareness did not overtly present as critical, it did manifest in the SME's list of knowledge, skills, abilities and other characteristics (KSAOs) that would delineate suitability of a superior candidate from an average candidate. Interesting to note, all but one KSAO on their suitability list related to situation awareness. These included the abilities to: make appropriate and timely decisions; prioritize information and tasks; analyze current situation and anticipate

changes; and, process multiple sources of information. These abilities all reflect levels 2 and 3 situation awareness.

CogScreen – AE

The U.S. Federal Aviation Association (FAA) ordered the design of an instrument that could be used for neuropsychological screening for pilot medical re-certification purposes in cases of known or suspected neurological and/or neuropsychiatric conditions or trauma such as head injury, alcoholism, and HIV (Taylor, O'Hara, Mumenthaler, & Yesavage, 2000). The resulting test developed was the CogScreen - AE. Despite this being a neuropsychological measure of brain functioning, the CogScreen- AE also measures the abilities required for flying (Kay, 2001), and interestingly enough, many constructs that relate to situation awareness. The CogScreen- AE test is computer-based and electronically scored. It aims to detect deficits or changes in attention, working memory, attention, visual-perceptual function, sequencing function, problem solving, calculation skills, reaction time, simultaneous information processing skills, executive function and numerous others (Kay, 1995).

CogScreen – AE Sub-tests and Constructs

There are generally 11 different CogScreen – AE sub-tests that comprise this battery, some having several conditions within each sub-test. A short description of each can be found at Table 1 with a more detailed explanation at Appendix A, including the constructs that each test purports to measure (Kay, 1995).

Table 1

Short Description of CogScreen – AE Sub-tests

Subtest	Description
Backward Digit Span (BDS)	Recall of a visual sequence of digits in reverse order.
Math (MAT)	Traditional math word problems with multiple choices answer formats.
Visual Sequence Comparison (VSC)	Comparison of two simultaneously presented series of letters and numbers (VSC).
Symbol Digit Coding (SDC)	Substitution of digits for symbols using a key, followed by immediate and delayed recall of symbol-digit pairs.
Matching to Sample (MTS)	Immediate recognition for a checkerboard pattern.
Manikin (MAN)	Mental rotation task requiring respondent to identify the hand in which a rotated human figure is holding a flag.
Divided Attention (DAT)	Employs a monitoring task which is presented alone and then in combination with the Visual Sequence Comparison task.
Auditory Sequence Comparison (ASC)	Comparison of two series of tone patterns.
Pathfinder (PF)	Visual sequencing and scanning task that requires respondents to sequence numbers, letters and an alternating set of numbers and letters while tapping in the centre of the appropriate box.
Shifting Attention (SAT)	Rule-acquisition and rule-application test requiring mental flexibility and conceptual reasoning.
Dual Task Tracking (DTT)	The first task is a visual-motor tracking test. The second task is a continuous memory task involving serial digit recall. The two tasks are then executed together to assess multi-tasking ability.

CogScreen – AE Measures

In general, measures are collected electronically and represent response speed, accuracy, and “thruput”, also referred to as efficiency (Kay, 1995). Some sub-tests also generate process measures that capture performance characteristics such as premature hits to gauge impulsivity. Appendix B provides a description of the CogScreen – AE measures in further detail.

CogScreen – AE Normative and Validation Research

Over a two-year period, the CogScreen - AE was administered in two normative studies with U.S. commercial airline pilots (N = 585), and Russian pilots (N = 225) (Kay, 1995). For the Russian study, a Cyrillic language version of CogScreen - AE was produced in order to obtain normative data from a diversely different country. Pilot groups were well matched on total flight hours, age and gender but not on final sample size, (N = 203) Russian versus (N = 584) U.S. pilots. The largest self-reported difference was computer familiarity, with 66% of the Russians identifying themselves as unfamiliar with computers in comparison to only 25 % of the U.S. pilots. Results indicated that computer experience played a significant factor in Pathfinder (PF) Letter and Math (MAT) measures, accounting for differences in performance between the two nationalities. The differences on PF Letter are also likely attributable to the Russian pilots’ unfamiliarity with the last half of the Cyrillic alphabet (Kay, 1995) while the large difference in Auditory Sequence Comparison (ASC) accuracy can be partially explained by the high levels of ambient noise in the cockpits of Russian commercial jet aircraft and patterns of alcohol use (something that may not have been screened for as extensively in

the Russian study as in the U.S. study). Kay posits that these few significant differences between U.S. and Russian pilots suggest that the CogScreen - AE is fairly robust to cultural differences and are explainable by language differences, computer literacy and occupational health issues (Kay, 1995). The Russian results should be read with caution since computer literacy is critical to performance on this computer - administered test battery.

Yakimovich, Strongin, Govoruschenko, Schroeder, and Kay (1994) demonstrated that variables from 4 of 13 CogScreen- AE tests (Cyrillic version) namely the Backward Digit Span (BDS), the Matching to Sample (MTS) Test, the Divided Attention (DAT) Dual task mode, and the Shifting Attention Test (SAT - Arrow direction) accounted for 30 - 45% of the variance in the performance index (flight violations per 100 hours of flight). Of note, it was possible for a pilot to obtain the same score with two very different patterns of performance. Thus the categorization of performance, number and type of violations make interpretation difficult. The large difference between the R^2 and adjusted R^2 suggests that there were too many predictors in the model that could have artificially inflated the R^2 .

Taylor, O'Hara, Mumenthaler and Yesavage (2000) assessed the relationship between CogScreen - AE, flight performance and age. They found that in order to establish the validity of CogScreen - AE as an occupationally - relevant assessment instrument, it is critical to demonstrate a relationship between CogScreen - AE and flight performance particularly to ensure that pilot selection does not result in high attrition. Taylor et al., (2000) reduced the number of predictors to five composite CogScreen - AE

factors, which included: (F1) speed/working memory, (F2) visual associative memory, (F3) motor coordination, (F4) tracking, and (F5) attribute identification. Using forward step-wise regression, the first four variables accounted for 45% variance in the flight simulator summary scores with pilot age, increasing the prediction further. None of the age relations favoured older pilots. Motor coordination and tracking were the only factors not significantly related to age. Overall, the data supported the validity of the CogScreen - AE as a cognitive battery that taps skills related to piloting in general terms, however there was no specific mention of situation awareness.

Cass and Parush (2009) conducted an exploratory factor analysis for CogScreen – AE. 16 variables produced a three-factor solution, explaining 73% variance and the best fit. The resulting factors were: (F1) visual scanning and tracking speed; (F2) selective attention; and, (F3) attribute identification. A cross-comparison of all CogScreen – AE factor analyses can be found in Cass and Parush (2009).

Individual Differences in Normative Research

In the normative research, age accounted for 9% or more of the variance in test performance but for only five measures, namely: SDC throughput, SAT (Instruction speed), VSC throughput, DTT Previous number (dual) accuracy, and SAT (Discovery) throughput (Kay, 1995). Significant gender differences were only found on the DTT boundary hits. In this test, the female pilots exhibited less control than the male pilots, in the motor coordination and tracking task. In a separate study, Callister, King, and Retzlaff (1996) found significant gender differences in approximately one-third of the variables, with the female pilots achieving better than half on these variables.

After controlling for the effects of age, education accounted for only 1.7% variance and in Pathfinder Letter speed only, as nearly 80% of the participants had 16 or more years of education. Computer literacy accounted for 5 % of variance in SDC throughput performance and even less in Math throughput (3%), DTT previous number (dual) accuracy and SAT (Discovery) throughput performance.

A comparison of airline participation revealed significant effects on eight speed, eight accuracy, five throughput and five process measures but with only four sub-tests with measures that accounted for more than 7% of variance in test performance. All significant effects revealed higher performance for larger airline carriers in comparison to the medium and small airline carriers (Kay, 1995).

Content Validity

Selection of CogScreen – AE domains was primarily based upon a review of aviation task analyses (Kay, 1995). The following cognitive functions were deemed to be

essential to skilled pilot performance: verbal comprehension, memory (encoding, storage and retrieval), visual scanning and perceptual speed, kinesthetic sensitivity, visual pattern or sequence comparison, memory search, reaction time, coordination, spatial orientation, rate control, application of rules, inductive and deductive reasoning, mental flexibility and focused sustained and divided attention (Kay, 1995). In a second phase survey, (N = 320) using the U.S. aviator normative sample, the tests considered most relevant to aviation were the DAT, the VSC, and the Math Test with more than 80% of the sample rating these tests as relevant. The SAT and the DTT tracking test were also rated highly relevant when they came online during the third phase.

Reliability

Test - retest reliability was determined from comparison of thruput and speed measures at baseline, 6-month and 12-month marks. Thruput measures were selected as the primary measure for reliability determination because they were normally distributed and encompassed both speed and accuracy of performance in a single measure (Kay, 1995). Values ranged from .69 - .80 with an average reliability coefficient of .80. Overall, the thruput measures demonstrated a very acceptable level of test reliability (Kay, 1995).

Research Question and Objectives of This Study

This research addressed the following question: Can CogScreen –AE predict pilot situation awareness? It was hypothesized that if the CogScreen – AE is a valid predictor of situation awareness, then the CogScreen – AE scores would have a positive relationship with the HelMET situation awareness performance scores. It was also

hypothesized that inexperienced pilots who scored high on the situation awareness simulated scenarios would also score high on the CogScreen – AE test. To investigate this research question and the two underlying hypotheses, this study was conducted in two phases: Phase 1 Cognitive task analysis; and Phase 2 Empirical testing. Both phases involved rotary wing CH - 124 Sea King pilots as subject matter experts (SMEs) for the cognitive task analysis and others as test participants.

Phase 1: Sea King Deck Landing Cognitive Task Analysis

As a pre-cursor to the experiment itself, a cognitive task analysis was conducted to identify the tasks of a routine yet complex pilot task, and to uncover the underlying situation awareness-related constructs and levels of each sub-task. An additional objective was to compare these constructs to those of the CogScreen – AE sub-tests and to create situation awareness-related SAGAT probes and freeze points at each critical way point for use in phase 2.

The selected task was landing a CH - 124 Sea King on the deck of a Canadian Patrol Frigate. The following questions were investigated through the cognitive task analysis:

- a. What are the critical way points or events involved in each type of deck-landing?
- b. What situation awareness-related constructs (and sub-constructs) are utilized at each way point?
- c. What information do you seek at this stage (level 1 - perception)?
- d. If you have this information, what does it mean (level 2 - comprehension)?

- e. What will this information mean in the near future (level 3 - projection)?
- f. What situation awareness-related probes could be asked throughout the critical way points in the scenario(s) to address these three levels of situation awareness?
- g. Where in the scenario should these probes be asked?

Method

Participants

The rotary wing stream was selected over fixed wing for this study given the additional psychomotor requirements involved in helicopter flying. The Sea King community was selected for its deck landing task given its level of difficulty, the criticality of its execution, the lack of deck landing simulation training provided to CH - 124 pilots, and the high level of situation awareness needed for this task.

Three experienced Sea King (Rotary Wing) pilots of 406 Squadron, 12 Wing Shearwater, NS volunteered to participate as SMEs over a one-week period to assist with the cognitive task analysis. SME 1 had more than 10 years experience and had logged 3500 hours on the Sea King; SME 2 had 6 - 10 years experience and had logged 1000 hours; SME 3 had 3 - 5 years experience and had logged 1300 hours. All three pilots had served in instructional and operational capacities, and had flown within the last two years.

Apparatus and Materials

The Helicopter Environmental Trainer (HelMET) was utilized for this study given its scripted method of flight demonstration (conducive for inexperienced pilots), its capability to freeze simulations, and to blank out the viewer's display, making SAGAT

an appropriate measure. The HelMET utilizes a binocular head-mounted display which affords superior visual cues through stereoscopic image generation as well as true motion parallax. These features aid in visual orientation and depth perception. A picture of HelMET can be viewed at Figure 1.

Although HelMET is a low-fidelity simulator, Defence Research and Development Canada's (DRDC Toronto) comparison of it with a high-fidelity, state-of-the-art simulator suggested that the HelMET was a good substitute for the high-fidelity simulator, in that pilots ($n = 12$) without Sea King experience, improved their performance over the course of numerous deck landings (Sterling, Magee, & Wallace, 2000). Also, there were no breaks in their learning curve between 40 HelMET deck landings and 40 subsequent high-fidelity simulator landings. These pilots also displayed superior performance conducting the high-fidelity deck landings in comparison to a placebo group that had no prior flight experience on either simulator (Sterling, Magee, & Wallace, 2000). HelMET was therefore rendered to be an acceptable test platform for this purpose.

Figure 1. HelMET Simulator including the participant cockpit seat (centre), instructor operator station (bottom of the picture) and large screens showing participant views (rear left and right).

Four scenarios were made available for this study. Scenario A was a free deck landing on a clear day. This scenario was used to familiarize participants on the HelMET prior to testing. Scenarios B, C, and D were used as trial scenarios. Scenario B was a haul down landing, on a foggy day, in moderate seas, with a 180 degree red approach. Scenario C was a free deck landing, on a clear night, in low-moderate seas, with a 165 degree green approach. Scenario D was a haul down landing, on a dark night, in moderate seas, with a 165 degree red approach. Sketches of each scenario are presented at Appendix C.

Procedure

The three SMEs each read and signed an informed consent form, Appendix D, and completed a demographics questionnaire, Appendix E. During the first two days, SMEs 1 and 2 grouped the tasks by critical way points: final approach fix plus .50 nautical miles; at the final approach fix - 200 ft (60.96 m), 115 ft (35.05 m) descent; 100 ft (30.48 m) and one nautical mile, prior to the half nautical mile, one-half nautical mile,

Delta Hover Astern, Signal Charlie, Delta Hover Abeam, High Hover, Low Hover and Weight on Wheels. (Numeric data is based on non-metric units and converted to the rounded SI equivalent).

SME 1 assumed the role of pilot while SME 2 assumed the role of co-pilot. In this capacity, SME 1 explained the tasks involved at each of the critical way points. For example, at the final approach fix plus 0.50 ft (.15 m), the task was to receive numbers from the ship, more specifically, the true winds, relative winds, speed and clearance to close (level 1 perception). SME 1 was then asked what that information meant to him (level 2 - comprehension). The numbers told him about the ship's position, and where the helicopter had to be in relation to the ship. Finally, he was asked what he could anticipate next (level 3 - projection). He stated that the ship was going to head into the wind or slightly to one side to achieve the helicopter recovery.

Next, SME 3 played the pilot role in the HelMET, talking through each of the three experimental scenarios, while SME 2 acted as the co-pilot. At each critical way point, each task or sub-task was analyzed to determine situation awareness-related probes that could be asked if the simulator was frozen with the screen blanked. The two SMEs conferred on viable probes, correct responses, and appropriate freeze points. With this information, SME 2 programmed the situation awareness probes into the HelMET program to create auto-stops for phase two empirical testing.

On the final day, a pilot study was conducted with SME 3 assuming the role of pilot participant. The principal investigator queried SME 3 on the various probes at the programmed freeze points. This pilot study confirmed the effectiveness of the probes,

timings, responses, freeze points, and the overall time required to run each scenario.

Despite helping with the probe creation, SME 3 did not anticipate certain probes, suggesting that he was not aware of the situation at all times despite his previous knowledge or his experience level.

Results

Each deck landing task was categorized by situation awareness- related constructs, broadly described as: spatial, attention, memory, perception, other cognitive functions (including deductive reasoning, math) and psychomotor coordination. The spatial construct was divided into spatial orientation (Kozlowski & Bryant, 1977) and mental rotation (Folk & Luce, 1987). Attention included: divided attention, visual monitoring, selective attention (Goldstein, 2005), and sustained attention (Sternberg, 2003). Memory included working memory and long-term memory involving recall and retention (Goldstein, 2005). Perception included visual processing, information processing speed (Smith & Kosslyn, 2006), and sequence processing (Smith & Kosslyn, 2006). Other cognitive functions consisted of deductive reasoning (Goldstein, 2005) and computational math skills (Medin, Ross, & Markman, 2005), while psychomotor coordination included motor coordination and visual motor tracking (Kay, 1995). The working definitions of these sub-constructs are defined at Appendix F. Table 2 below displays a summary of 323 instances of situation awareness-related constructs/sub-constructs across the three experimental scenarios. Attention had the highest frequency (n = 93); memory (n = 91) had the second highest, and perception (n = 86) had the third highest. The Spatial construct had the lowest frequency (n = 17).

Table 2

Frequency of Situation Awareness (SA) Constructs for each of the Scenarios

Construct	Sub-Construct	Scenario B	Scenario C	Scenario D	Construct Totals
Spatial	Spatial orientation	3	3	3	9
	Mental rotation	2	3	3	8
	Sub-total:	5	6	6	17
Attention	Divided attention	11	4	8	23
	Visual monitoring	8	8	8	24
	Selective attention	9	7	8	24
	Sustained attention	11	3	8	22
	Sub-total:	39	22	32	93
Memory	Working memory	20	14	20	54
	Long term memory	17	6	14	37
	Sub-total:	37	20	34	91
Perception	Visual processing	19	10	16	45
	Information processing speed	12	5	7	24
	Sequence processing	7	3	7	17

	Sub-total:	38	18	30	86
Other Cognitive Functions	Deductive reasoning	13	8	13	34
	Computational Math Skills	2	1	2	5
	Sub-total:	15	9	15	39
Psychomotor coordination	Motor coordination	11	3	9	23
	Visual motor tracking	11	3	9	23
	Sub-total:	22	6	18	46
	Totals:	161	88	139	323

Appendices G, H and I are scenario summaries that provide the details of the cognitive task analysis of each experimental scenario (B, C and D). These include the critical way points, freeze points, probes/responses, highest situation awareness level for probes, situation awareness constructs, and the CogScreen – AE sub-tests aimed at measuring the related constructs.

Table 3 provides a tally of the situation awareness probes that were defined for each level and scenario. Although there were fewer level 1 probes than levels 2 or 3, the number of probes for each scenario is commensurate with the length of each scenario. Scenario B was the longest scenario and scenario C was the shortest.

Table 3

Number of Situation Awareness (SA) Probes by Level and Scenario

	Scenario B	Scenario C	Scenario D
SA level 1 probes	5	3	5
SA level 2 probes	10	6	8
SA level 3 probes	10	8	10
Total probes per scenario	25	17	23

CogScreen AE and Situation Awareness Constructs: A Proposed Synthesis

The preceding review of CogScreen –AE covered its sub-tests, constructs, measures, reliability, validity and normative research including individual differences. The cognitive task analysis demonstrated that the Sea King deck landing task encompasses the situation awareness constructs and all three levels of situation awareness levels. The question is whether such a test battery can be considered for testing pilot situation awareness. Table 4 demonstrates linkages between situation awareness constructs, common errors in aviation in those realms, and the CogScreen – AE sub-tests that purport to address the situation awareness. These linkages suggest that further exploration of CogScreen-AE as a possible selection predictor of situation awareness is reasonable and justified. Table 4 also delineates the hypothesized detailed relationship between situation awareness and CogScreen - AE as a function of their related constructs and typical errors.

Table 4

Situation Awareness (SA) and CogScreen – AE Construct Matching

SA Constructs	Common Errors	CogScreen – Subtest	CogScreen Constructs
Spatial			
Orientation	Disorientation	Matching to Sample (MTS)	Spatial orientation
Rotation		Matching to Sample (MTS) Manikin(MAN)	Mental rotation
Attention			
Switching	Workload	Math (MAT) Pathfinder (PF) Shifting Attention (SAT)	Concentration Shift mental set
Selective	Attention narrowing	Visual Sequence (VSC) Backward Digit Span (BDS) Symbol Digit Code (SDC) Math (MAT)	Visual attention Attention
Visual monitoring	Distractions	Auditory Sequence (ASC)	Auditory attention
Divided attention		Divided Attention (DAT) Dual Task Tracking (DTT) Shifting Attention (SAT) Dual Task Tracking (DTT) Shifting Attention (SAT)	Divided attention Sustained attention Perseverative tendencies
Memory			
Working memory	Memory loss	Divided Attention (DAT)	

Long-term memory		Shifting Attention (SAT)	
		Visual Sequence(VSC)	
		Pathfinder (PF)	
		Backward Digit Span (BDS)	Working memory
		Math (MAT)	
		Symbol Digit Code (SDC)	
		Dual Task Tracking (DTT)	
		Symbol Digit Code (SDC)	Retention
<hr/>			
Perception			
	Pattern matching	Auditory Sequence (ASC)	Detecting differences Attribute identification
Visual processing	Scanning omissions	Symbol Digit Coding (SDC) Shifting Attention (SAT) Pathfinder (PF)	Visual processing
Sequence processing		Visual Sequence (VSC)	Verbo-sequential processing
		Divided Attention (DAT)	
		Dual Attention Task (DAT)	Visual monitoring
		Manikin (MAN)	Visual spatial perception
Information processing		Symbol Digit Coding (SDC)	Information processing speed
		Matching to Sample (MTS)	Visual perceptual speed
		Visual Sequence VSC)	
		Divided Attention (DAT)	

Other Cognitive Functions	Math (MAT)	Reading comprehension
		Logical reasoning
		Computational math skills
	Pathfinder (PF)	Organizing
	Deductive reasoning	Shifting attention (SAT)
Perseverative errors		
Mental flexibility		
Psychomotor Coordination	Pathfinder (PF)	Motor coordination
	Dual Task Tracking (DTT)	Visual motor tracking

Summary

Analyses of the tasks involved in the three deck landing scenarios, along with their associated situation awareness constructs and the three levels of situation awareness were performed. The situation awareness-related probes, their related freeze timings, and expected responses were created with SME assistance. The cognitive task analysis was completed by matching the situation awareness constructs with related CogScreen –AE sub-tests. Appendices G, H, and I summarize the cognitive task analysis. These summaries became the probe allocation worksheets for Phase 2 simulated situation awareness testing and were utilized during the empirical phase.

Phase 2: Situation Awareness and CogScreen – AE Testing

The objective of phase two was to assess the situation awareness performance of pilots conducting virtual deck landings and relate it to their accuracy and thruput scores on the CogScreen - AE test in order to respond to the two hypotheses. Significant results would suggest that individual differences in situation awareness exist despite a lack of

training or experience and that some inexperienced pilots in the population may have the ability to excel in situation awareness. Such results would support taking the CogScreen – AE beyond the proof of concept level provided by this study, and developing it into a viable selection tool for pilot's situation awareness.

Method

Participants

Twenty-seven CF Sea King pilots from 12 Wing Shearwater, NS, took part in this study. The participants were divided into two experience groups: inexperienced pilots ($n = 13$) and experienced pilots ($n = 14$). Division into these groups was based on responses to the demographic questionnaire (Appendix E). Those pilots with zero hours on the Sea King were slated into the inexperienced group. Operational pilots with several hundreds of hours formed the experienced group. The latter group ranged from 430 hours to 4100 hours with a mean of 1483.93 Sea King hours. Although military participants are not permitted to accept participation incentives they were deemed to be willing participants. Whether experienced or inexperienced, their perceived incentive was their time with the simulator since their participation did not impact, detract, or reduce their allocated Sea King flying hours or training time. In the case of the inexperienced pilots (who were awaiting training) they gained valuable insight, exposure and a realistic job preview of an important Sea King task, taught only at the advanced stages of flying training.

The age of the inexperienced pilots ranged from 20 - 30 years with a mean age of 24 years ($SE = .82$). The experienced pilot group ranged from 26 - 49 years with a mean age of 38 ($SE = 2.05$). Given CF entrance standards, both groups were homogeneous

with regards to their education levels. The inexperienced group's years of education ranged from 13 - 17 years with a mean of 16 years. The experienced group's years of education ranged from 14 - 18 years with a mean of 16 years. Gender, race and language were not of interest to this study nor sufficiently represented to assess such differences, with only two inexperienced females, one African-Canadian, and one Francophone (who completed the tests in English).

Apparatus and Materials

The HelMET deck landing simulator was used to assess participants' situation awareness and was described in phase 1. The scenarios (B, C, and D) used in the cognitive task analysis, were also utilized in phase 2. Lesson plans for a free deck landing and a haul down landing were provided to the inexperienced participants prior to simulator time, given their unfamiliarity with the Sea King or the deck landings. Two CogScreen – AE test stations were rented for testing two participants at a time. Each of these test stations was equipped with an Intel Pentium processor (ASUS EEE box), MS Windows XP operating system, 15-inch ELO touch screen monitor with a 60 Hz minimum refresh rate, screen resolution of 1024 x 768, a sound adapter to support Direct X, stylus for onscreen answer selection, plus a standard headset, keyboard and mouse. Each terminal was calibrated, upon initial installation, and once weekly to ensure precision of stylus use with the touch screen. Pens were used to complete the informed consents, pre-briefs, demographic questionnaires and debrief forms.

Study Design

The study was run and analyzed as a 2 x 3 x 3 x 3 (Experience x Order x Scenario x Situation awareness levels) mixed design. Experience and order were between participant independent variables; scenario and situation awareness levels were repeated measures.

Complete randomization of the situation awareness probes with respect to their level was not accomplished completely. The intention was to give the first participant the first probe in each of the critical way points, and to give the second participant the second probe in each of the critical way points, and so on. The different scenario lengths and the common probes throughout each of the three scenarios resulted, sometimes, with the same probe for the same participant in a subsequent scenario. In such cases, the participant was allocated a different probe in that critical way point that had not already been asked previously. The objective was to have two probes for each situation awareness level for a total of six probes per scenario, yet only one probe for each situation awareness level could be analyzed. The need for reallocation, meant some participants had a higher frequency of one situation awareness level probe and less of another (particularly level 1 probes), since there were fewer number of these in each scenario.

Procedure

Participants were recruited through a poster advertisement sent via 12 Wing's e-mail system. The ad indicated that the study aimed at assessing a cognitive test to improve pilot selection. Interested candidates contacted a third party coordinator for

scheduling of a morning or an afternoon test session. Participants were organized in pairs for the purpose of efficiently running the test sessions. Upon arrival at the simulation centre, each pilot signed an informed consent (Appendix J), demographics questionnaire (Appendix E), and a pre-brief form (Appendix K or L, as applicable), prior to receiving further instructions.

Upon obtaining consent, the two pilots were seated in front of the CogScreen – AE test stations and the principal researcher read introductory instructions. These instructions can be viewed at Appendix M. For each of the CogScreen – AE sub-tests, the participants read the on-screen instructions, and completed the respective practice session. All participants completed the CogScreen – AE within one hour.

Upon completion, they were each given a return time for simulator testing. All candidates had a minimum of a one half-hour break to let their eyes rest before the simulator testing. Upon return, inexperienced pilot candidates were given two of the HelMET tutorial lesson plans (a free deck landing and a haul down landing) to study over a 30 minute period. After that, they were given a 15 minute break to relax before the simulator testing. From this point onwards, both groups were given the same instructions and the order of scenario presentation was counterbalanced using Latin Square. Appendix N shows the order of presentation for each group and each participant.

The experiment started with the participant strapping into the pilot chair and making the necessary adjustments for the cockpit seat and head-mounted display before reading the scenario set-up sheet. When ready, scenario A was launched as a walk-through familiarization flight. The principal investigator randomly froze the simulation

throughout the scenario to familiarize the participant with the motion cessation and blanking of the vision display. Although the simulator system was designed to run as scripted, participants were instructed to actively engage during the trials as if they were actually flying. This was important since they would have to respond to questions about the scenario. To help stay engaged, participants were instructed to manipulate the stick and collective and to talk aloud as they would to their crew and to respond to the ship over the radio. As with scenario A, the participants were given a scenario set-up sheet prior to the start of each experimental scenario. These can be viewed at Appendix O. Participants were given 10 minute rest breaks between scenarios.

Upon completion of the three scenarios, each participant was asked to read and sign a de-brief form (Appendix P) which further explained the purpose of the research and the importance of not disclosing their experience and testing content or the situation awareness probes with other pilots who may participate at a later date. They also participated in a short de-brief interview with the principal investigator to learn more about their perceptions of situation awareness use during the test trials.

Results

Analysis Overview

The following analyses were performed:

1. Differences in situation awareness accuracy were examined as a function of pilot experience.
2. Participants' mean situation awareness accuracy scores were split at the median in order to create high and low situation awareness performance

groups. The resulting IV was also used to assess the relationship between performance and CogScreen - AE scores (see #4).

3. Confidence ratings were examined as a function of pilot experience and situation awareness accuracy.
4. A series of one-way ANOVAs were used to assess the relationship between experience levels and situation awareness performance (IVs) with CogScreen - AE accuracy and throughput scores. (The explanation for running several one-way ANOVAs as opposed to a single multi-way ANOVA is presented later in this chapter).
5. Bi-modal CogScreen - AE distributions were examined for meaningful differences between high and low CogScreen - AE performance as a function of experience, and also as a function of situation awareness performance groups.
6. Finally, the de-brief interview data was analyzed to explore differences in perception of situation awareness usage (as opposed to procedural knowledge, for example) during the scenarios.

Data Diagnostics and Cleaning

Situation awareness accuracy scores and CogScreen – AE scores were checked for outliers, normality and missing data. SPSS systematically removed cases that were missing situation awareness scores. This left a reduced situation awareness task sample of $N = 21$. A comparison with and without mean imputation revealed no difference in median cut-off. For this reason, $N = 27$ was maintained to preserve the already small

sample. Given that only two groups were being compared, post hoc comparison corrections were not required. Since each participant completed the three scenarios in succession, order of scenario administration was counterbalanced to reduce any order effects. All tests met the sphericity assumption unless otherwise noted.

A test was conducted to assess whether experience levels could be a covariate. Experience levels did not sufficiently correlate with the dependent variables (CogScreen – AE scores) but correlated strongly with the independent variable, situation awareness performance. For this reason, experience level was used as an IV in all the analyses.

HelMET Simulator Situation Awareness Accuracy

Simulator situation awareness accuracy was analyzed with a 2 x 3 x 3 x 3 (Experience level x Scenario order x Scenario x Situation awareness levels) mixed design. With sphericity assumed, a three-way interaction between experience, order and scenario approached significance ($F(4,42) = 2.55, p = .05, \eta^2 = .20$). Each experience level's situation awareness performance varied as a function of the scenario and of the scenario order, as shown in Appendix Q. Pilots of both experience levels who completed the situation awareness simulator testing in D-B-C order demonstrated the highest performance. These high accuracy scores could not be attributed to any one scenario since the inexperienced pilots scored highest on scenario B ($M = .87, SE = .10$) and the experienced pilots scored highest on scenario D ($M = 1.00, SE = .13$). Significant main effects for scenario ($F(2,42) = 3.86, p = .03, \eta^2 = .16$) and for experience levels ($F(1,21) = 10.24, p < .01, \eta^2 = .33$) could not be interpreted with any certainty in light of the three-way interaction.

There was a significant two-way interaction where performance in a given scenario varied as a function of the scenario order ($F(4,42) = 6.73, p < .01, \eta^2 = .39$). Scenarios C and D resulted in higher situation awareness mean accuracy when placed after scenario B (B-C-D). Scenario C had the highest situation awareness mean accuracy when presented first (order C-D-B), scenario B had the highest mean accuracy when it was in the middle position (D-B-C). The mean accuracy for situation awareness levels was also significant ($F(2,42) = 4.08, p = .02, \eta^2 = .16$) with level 2 (comprehension) having the highest mean accuracy; significantly higher than level 3 (projection). ($M^{diff} = .18, SE = .06$).

There seems to be no clear and systematic pattern to the effect of scenario order. These situation awareness accuracy scores involving scenario order cannot be interpreted in any sensible fashion that helps test the hypotheses and address the research question. In view of this and the fact that order was counter-balanced across all participants, a decision was made to remove the scenario order variable from any further situation awareness accuracy analyses.

With experience levels as the sole between-subjects IV, a 2 x 3 x 3 (Experience x Scenarios x Situation levels) mixed repeated measures design was utilized. There were no significant interactions. There were however, significant differences between the experience levels' situation awareness performance ($F(1,25) = 10.77, p < .01, \eta^2 = .30$) with the experienced pilots having higher accuracy than the inexperienced pilots. Accuracy for the three situation awareness levels also varied significantly ($F(2,50) = 4.36, p = .02, \eta^2 = .15$) with level 2 (comprehension) probes having the highest accuracy

compared to level 1 (perception) and level 3 (projection) probes, as can be seen in Figure 2. Situation awareness levels retained a consistent main effect even though order of presentation was no longer part of the analysis.

Figure 2. Mean accuracy for situation awareness levels (along with SE) showing level 2 (comprehension) having the highest accuracy, for each of the two experience groups.

Confidence Ratings for Situation Awareness Probe Responses

The same original 2 x 3 x 3 x 3 (Experience x Order x Scenarios x Situation awareness levels) mixed repeated design was attempted for confidence ratings. A significant three-way interaction was found for confidence ratings between scenario order, experience and scenario ($F(4,42) = 3.81, p = .01, \eta p^2 = .27$); similar to that of situation awareness accuracy scores. This interaction suggests that confidence varied for each of the experience level as a function of the scenario and the order in which it was presented. The experienced group attained their highest confidence in the free deck

landing (scenario C), when it was presented as the last scenario (D-B-C). The inexperienced group consistently showed their highest confidence in scenario D (haul down landing) regardless of the order presented but were equally confident on scenarios B and D (haul down landings) when receiving C-D-B order. Their highest overall performance was on scenario D when they received it first (D-B-C).

A two-way interaction also was found between scenario and situation awareness levels which suggested that confidence varied as a function of the situation awareness levels and scenario presented. Scenario B (haul down) demonstrated the highest means on level 2 situation awareness probes while scenarios C (free deck) and D (haul down) demonstrated the highest confidence ratings on level three situation awareness probes.

There were also significant main effects for experience level ($F(1,21) = 34.99$, $p < .01$, $\eta^2 = .63$) with the experienced pilots expressing higher confidence than the inexperienced pilots. Order was approaching a significant main effect as well ($F(2,21) = 3.38$, $p = .05$, $\eta^2 = .24$). Descriptive statistics are presented in Appendix Q.

Scenario order impacted confidence ratings for experience levels, throughout the scenarios and across situation awareness levels. As seen with the situation awareness performance accuracy scores, there does not seem to be any clear or systematic pattern in the effect of scenario presentation order on the data. The findings that include order cannot be interpreted in any logical manner that helps test the hypotheses and address the research questions. In view of this, a decision was made to remove the order variable from any further confidence rating analyses.

Having removed scenario order as a variable, a subsequent repeated measures analysis was conducted for confidence ratings with experience level as the sole between-subjects variable. The analysis addressed a 2 x 3 x 3 (Experience level x Scenarios x Situation awareness levels) mixed design. The significant two-way interaction for scenario and situation awareness levels remained when order was not a factor. This suggests that confidence in the situation awareness level probes depended upon the scenario presented, or the confidence in scenario was contingent upon the situation awareness level probes. Once again, this interaction does not contribute to the analysis of the hypotheses. Experience levels also remained significant ($F(1,25) = 27.74, p < .01, \eta^2 = .53$) without order as a factor, with the experienced pilots reporting higher confidence than the inexperienced pilots. Descriptive statistics are presented at Appendix Q.

Situation Awareness Accuracy and Confidence Ratings

The relationship between situation awareness performance accuracy scores and confidence ratings was explored. Figure 3 shows that the experienced pilots were consistently more confident and more accurate. It also shows a significant positive linear relationship between accuracy and confidence for the inexperienced pilots ($r = .83, R^2 = .68, b = 2.69, t(1,11) = 4.87, p < .01$); as their accuracy increased, so did their confidence.

Figure 3. A positive relationship between situation awareness accuracy and confidence ratings for inexperienced pilots.

These confidence ratings were also assessed in regards to hits and false alarms in line with signal detection theory. A “hit” is defined as the correct detection of a real signal while a “false alarm” is defined as an incorrect report of a non-signal (McGuiness, 2004). In this study, a hit was operationalized as high confidence associated with a correct answer while a false alarm is high confidence associated with an incorrect answer. False alarms are indicative of dangerous pilot performance since they represent over-confidence when making an error in accuracy. Figure 4 is a graphical depiction of the false alarms in relation to the hits. The diagonal line divides performance attributable to hits (accuracy with high confidence) from performance attributable to false alarms (inaccuracy with high confidence). The results show that neither experience level incurred more than one false alarm amongst its members. However, the experienced pilots clearly had more hits (confidence with accuracy) than the inexperienced pilots.

Figure 4. Mean proportion of hits as a function of mean proportion false alarms for each of the two experience groups. The diagonal line helps to distinguish between the “good” performance area, above the diagonal, from the “poor” below the diagonal.

Pilot Perceptions of Situation Awareness Use

Gauging participant's perceptions on the use of situation awareness was also of interest considering situation awareness has different meanings to different people. Given the working definition (Endsley, 1988) during post-experiment debriefs, participants were asked what percentage of the time they thought they were using situation awareness versus procedural knowledge during the scenarios. Inexperienced pilots thought they were using situation awareness much more often (*Mode* = 70%) than the experienced pilots (*Mode* = 30%). A median runs test revealed a median of 60% for the 21 participants that responded to this question. Nine pilots reported using situation awareness less than 60% of the time, while 12 pilots reported using situation awareness

more than 60% of the time. However these differences were not significantly different from one another.

CogScreen – AE Analyses

Preparation for CogScreen – AE analyses

The mean situation awareness accuracy scores for all cases were split at the median to create high and low situation awareness performance groups. This situation awareness performance group variable became a focal between-subjects IV in assessing CogScreen – AE performance. Situation awareness performance scores rendered placement of thirteen experienced pilots and five inexperienced pilots into the high situation awareness performance group ($n = 18$); and, one experienced pilot and eight inexperienced pilots into the low situation awareness performance group ($n = 9$).

Assessment of ANCOVA Appropriateness

ANCOVA was considered to be the appropriate method of analysis for CogScreen – AE given its ability to reduce error variance and increase power while neutralizing the effects of experience across the high and low situation awareness performance groups. In assessing experience as a potential covariate, correlations were run between experience and the CogScreen - AE accuracy, and thruput scores (DVs) to assess relationships. There were significant relationships between experience and the CogScreen - AE thruput scores for only two sub-tests: SDC thruput scores ($r = -.492, p < .01$), and SAT arrow color ($r = -.426, p = .03$); significance was approaching for the SAT discovery condition ($r = -.386, p = .05$). Experience also correlated with the high/low situation awareness

performance group (the focal IV) ($r = .860, p < .01$) which rendered the ANCOVA to be inappropriate to pursue further.

Two-way ANOVAs were also deemed inappropriate in that there was only one experienced pilot represented in the low situation awareness accuracy performance group causing serious cell inequalities. For this reason, two separate one-way ANOVA analyses were conducted for each of the two between-subjects IVs (experience and situation awareness performance), with the CogScreen – AE – accuracy and throughput scores.

CogScreen – AE Performance as a Function of Experience Groups

Differences in accuracy were approaching significance on the DTT- Previous number alone task compared to when it was presented in the dual mode with a motor tracking task. The inexperienced pilots had a smaller accuracy difference score between the one-task condition and the two-task condition, suggesting that they may have had less difficulty than the experienced pilots. However, both groups had higher accuracy on the single task compared to the dual (multi-tasking) test condition.

There were significant throughput differences between the experience levels on the SDC test ($F(1,25) = 7.97, p < .01, \eta^2 = .24$) and SAT (arrow color condition) ($F(1,25) = 5.54, p = .03, \eta^2 = .18$) with the inexperienced pilots having higher throughput scores. Two other SAT sub-tests, discovery ($F(1,20) = 4.39, p = .05, \eta^2 = .15$), and instruction ($F(1,25) = 3.89, p = .06, \eta^2 = .13$) approached significance again with the inexperienced pilots performing better.

*CogScreen – AE Performance as a Function of Situation Awareness Performance**Groups*

Levene's equality of variance indicated sphericity violations for the immediate recall ($F(1,25) = 33.33, p < .01$) and for the delayed recall ($F(1,25) = 35.58, p < .01$) tests. Therefore corrected models were assessed. Significant accuracy differences were found between the two situation awareness performance groups on the two Symbol digit recall sub-tests; immediate ($F(1,25) = 6.26, p = .02, \eta^2 = .20$) and delayed recall ($F(1,25) = 6.38, p = .02, \eta^2 = .20$) with the high situation awareness performance group performing with greater accuracy than the low situation awareness performance group. The low situation awareness group however did exhibit an increase in accuracy on the delayed recall test in comparison to their immediate recall as can be seen in Figure 5.

Figure 5. Situation awareness performance groups' mean accuracy scores on Symbol Digit Coding immediate and delayed recall tests.

CogScreen – AE Thruput Scores

The situation awareness performance groups did not exhibit any significant differences on the CogScreen – AE thruput scores. This suggests that the situation awareness performance groups were similar in efficiency scores despite differences in situation awareness performance accuracy.

CogScreen – AE Group Comparisons Based on Bi-Modal Distributions

The presence of bi-modal distributions in the accuracy and thruput scores of the various sub-tests was explored in order to provide a thorough CogScreen – AE analysis. The rationale was that a bi-modal distribution would imply the existence of high and low performance groups in the CogScreen-AE tests. Five tests had bi-modal distributions: Backward digit span (BDS) accuracy; Dual task tracking (DTT) (previous alone) accuracy; Manikin (MAN) thruput; Divided attention test sequence comparison (DATSC) thruput; and, Pathfinder (PF) (letter) thruput. High and low CogScreen – AE sub-test groups were created by dividing at the median between their two respective modes. These two groups were then examined, using Chi-Square Tests of Independence, in relation to high and low situation awareness performance groups from the HelMET simulator testing and in relation to the experience groups. The inexperienced pilots were significantly more efficient ($\chi^2(2, N = 27) = 11.23, p < .05$) in thruput on the Pathfinder letter sub-test (Table 5) and significantly more accurate ($\chi^2(1, N = 27) = 6.23, p < .05$) on the DTT (Previous number alone) sub-test (Table 6). The high situation awareness performance group was also more accurate ($\chi^2(1, N = 27) = 8.00, p < .05$) on the DTT test

(Table 7) than the low situation awareness performance group. There were no significant findings for the situation awareness performance groups with CogScreen – AE throughput.

Table 5

Pathfinder Letter Thruput Groups Observed Frequencies as a Function of Experience Levels

	Low Pathfinder Letter Group	High Pathfinder Letter Group
Inexperienced	3	10
Experienced	8	6

Table 6

Dual Task Tracking Previous Number Alone Accuracy Groups Observed Frequencies as a Function of Experience Levels

	Low Dual Task Tracking Previous Number Alone Group	High Dual Task Tracking Previous Number Alone Group
Inexperienced	2	11
Experienced	4	10

Table 7

Dual Task Tracking Previous Number Alone (DTTPNA) Accuracy Groups Observed Frequencies as a Function of Situation Awareness Performance Groups

	Low Dual Task Tracking Previous Number Alone Group	High Dual Task Tracking Previous Number Alone Group
Low situation awareness group	3	6
High situation awareness group	3	15

Discussion

Summary and Account of Results

This study addressed the following research question, “Can situation awareness be predicted by the CogScreen – AE?” To assess the relationship between situation awareness and the test battery, situation awareness performance was measured during three HelMET simulator-based helicopter deck landings. Performance was analyzed as a function of the CogScreen – AE scores, and overall provided partial support for the two study hypotheses:

Hypothesis 1: There was a positive relationship between situation awareness performance scores and CogScreen –AE since those in the high situation awareness performance group had greater accuracy on the SDC test - immediate and delayed recall tests, and in the DTT Previous number alone task. These positive relationships demonstrate that the CogScreen – AE can predict situation awareness performance in the memory components of situation awareness.

Hypothesis 2: The inexperienced pilots who scored with greater accuracy on the situation awareness task also scored higher on the SDC immediate and delayed recall conditions and the DTT Previous number alone task. This demonstrates that experience or training is not a necessary pre-cursor to effective situation awareness. These pilots demonstrated that individual differences in memory recall, retention, working memory, attribute identification as well as motor tracking are important and that there is a potential to measure them during selection.

Situation Awareness Accuracy

Simulator situation awareness performance varied as a function of experience level, with the experienced pilots performing better than the inexperienced pilots. Accuracy also varied significantly for situation awareness level, with level 2 comprehension, resulting in the highest situation awareness accuracy.

It is not surprising that the experienced pilots scored higher than the inexperienced pilots on deck landing simulations given their advanced training and experience. It was surprising however, that the level 2 probes resulted in significantly higher situation awareness performance than either levels 1 or 3 probes. A possible theoretical account for this finding is further explored under *Theoretical Implications*.

Confidence in Situation Awareness Answers

Experience levels showed clear main effects, with the experienced pilots being significantly more confident. The experienced pilots' confidence does not come as a surprise given their training and experience hours of Sea King flying. In addition, there was a two-way interaction between scenario and situation awareness level. The two-way interaction indicates that confidence on the situation awareness level probes depended on the scenario or vice versa. Level 2 comprehension probes resulted in the highest confidence in Scenario B while level 3 projection probes resulted in the highest confidence for scenarios C and D. Although this interaction is not easily explained there was a positive relationship between situation awareness accuracy and confidence for the inexperienced pilots with confidence increasing with accuracy performance. The

experienced pilots, however, were consistently confident and accurate throughout the scenarios. When accuracy and confidence were analyzed as hits and false alarms, the experienced pilots were very consistent in hits demonstrating that they knew they were accurate. The inexperienced pilots were less accurate and less confident but nevertheless exhibited few false alarms.

The positive relationship between accuracy and confidence for the inexperienced pilots may reflect learning or practice effect. As they became more experienced with the task, through the simulator scenarios, their confidence may have increased. The experienced pilots already possessed procedural knowledge which may have helped them gauge their accuracy and remain confident. The few false alarms for the inexperienced pilots demonstrate that they realized their limitations with limited training and experience at time of testing, and showed that they were not trying to compensate for inaccuracy with artificial confidence; thus an important trait for pilot candidates.

CogScreen – AE Performance as a Function of Experience Groups

There were no significant CogScreen – AE accuracy differences between the experience groups with the exception of the DTT multi-tasking test. Both experience groups scored higher in accuracy on the Previous number (alone) task in comparison to when this task was combined with the Tracking task (dual task condition), in assessing multi-tasking ability. The inexperienced group however approached significance in narrowing the difference in accuracy between the two conditions. They were also more efficient than the experienced pilots in learning the SDC symbol-digit pairings, compared to the experienced pilots. The inexperienced pilots also demonstrated significantly

greater efficiency than the experienced pilots in the Shifting attention test (arrow color) and they approached significance for the instruction and discovery conditions.

A lack of significant differences in accuracy between the experience groups may be attributable to their homogenous entry standards including highest education levels. The tests could also have been too easy for the pilots particularly since the CogScreen – AE was designed as a neuropsychological instrument to assess deficiencies or changes in cognition; not designed as a cognitive ability test.

The significant differences in throughput between the groups suggest that the inexperienced pilot group was more efficient than the experienced pilots at learning the symbol-digit pairings, identifying attributes and using their working memory. They were also quite competent at new rule learning, trial-and-error, and cognitive flexibility for the Shifting attention tests. As pilots in training, it is not uncommon for them to be highly conscientious and motivated to perform their best and work as quickly and as accurately as possible. Conversely, the experienced pilots did not seem to work as quickly. During the debrief interviews, several experienced participants revealed that there is typically ample time to execute tasks in the Sea King cockpit; and they are not trained to react with speed unless an emergency ensues. For this reason, the experienced pilots (on their own or as part of the high situation awareness performance group) may have traded off speed for accuracy; having less sense of urgency in both their simulator performance and the CogScreen – AE tests. The experience group did not score significantly higher in efficiency (throughput) than the inexperienced group on any of the CogScreen – AE tests. This suggests that the inexperienced pilots were actually faster which resulted in superior

thruput performance. Applying this to Sea King flying, speed does not appear to be critical to success of a Sea King pilot; that or age was impacting the performance of the experienced group.

High and low DTT groups were defined given the bi-modal distribution of the DTT accuracy results. These groups were compared as a function of the two experience groups. This test further confirmed the inexperienced pilots were more accurate on the DTT previous number task than the experienced pilots. This suggests that the inexperienced pilots had less difficulty with the multi-tasking test than the experienced pilots, utilizing working memory and psychomotor coordination at recalling/tapping the previous number while a new number was being presented.

High and low PF letter groups were defined given the bi-modal distribution of the Pathfinder letter thruput scores. The inexperienced pilots were more efficient on the PF letter test than the experienced pilots. This means that the inexperienced pilots worked more quickly and accurately at tracking the alphabet sequence on a shifting grid and pin-pointing the centre of the letter while maintaining their speed. The reason for the inexperienced pilots' superior performance on the DTT and the PF sub-tests might be attributable to generational differences in that the younger pilots are likely to play more computer games than the experienced pilots. By doing so, they may be honing their tracking skills, speed, as well as their memory skills. Age may also have affected their reaction times since the inexperienced group had a mean age of ten years less than the experienced pilots.

CogScreen – AE Performance as a Function of Situation Awareness Groups

Close examination of the CogScreen – AE tests show that the high situation awareness performance group was significantly more accurate than the low performance group on the SDC immediate and delayed recall sub-tests. There were no significant differences between the two situation awareness groups' thruput scores.

All but one experienced pilot scored high enough to be classified into the high situation awareness performance group. Also, 38% of the inexperienced pilots scored high enough to be classified into the high situation awareness performance group. This group's accuracy on the immediate and delayed recall (memory) test suggests that this sub-test was predictive of high situation awareness performance given the group's high mean accuracy on the situation awareness simulator testing. The lack of findings from the thruput scores suggests that either there was insufficient power to produce more significant findings or that the thruput scores are not predictive of situation awareness. As noted above, based on information from experienced pilot debriefs, speed is not essential for the majority of Sea King tasks. If this is the case, then thruput should not be considered for predictive testing.

The high situation awareness performance group was more accurate on the DTT Previous number alone task. Since the experienced group did not perform significantly higher than the inexperienced pilots on any of the sub-tests and the inexperienced pilots contributed to the high situation awareness scores, it is plausible that the inexperienced group tipped the balance with these sub-tests resulting in higher observations on DTT Previous number alone task. Regardless, the high situation awareness performance

group's higher accuracy shows that attribute identification, working memory and tracking skills relate to individual differences and can be predicted using this CogScreen – AE sub-test.

Theoretical Implications

Situation Awareness Levels

An arising question is why situation awareness level 2 (comprehension) probes resulted in higher mean accuracy than either level 1 (perception) probes or level 3 (projection) probes. Given the hierarchical nature of the situation awareness levels, it stands to reason that there would be more perception of cues than actual comprehension or projection. However this was not the case. It is possible that some level 1 cues were missed or ignored, since they could not be comprehended. Only those that made sense were acknowledged. This account is in line with previous studies (Endsley, 1995b, Jones & Endsley, 1996) which reported that most aviation mishaps occur at level 1 (perception), with observation failures cited as one of the reasons.

These results also coincide with previous research by Shook, Garland, Bandiero, Endsley, and Coello, (2000) where flight instructors were asked to note percentages of moderate to frequent situation awareness problems affecting inexperienced pilots. The flight instructors noted the lowest percentage of moderate to frequent situation awareness problems on all level 2 comprehension items (70%) compared to level 1 perception items where the flight instructors noted 80% moderate to frequent situation awareness problems or level 3 projection items where flight instructors noted (90%) moderate to frequent situation awareness problems.

Since level 3 projection is considered difficult for many pilots and typically required of expert level pilots (Endsley, 2000), it is not a surprise that there was less accuracy on level 3 probes. While this may explain the poor level 3 performance of inexperienced pilots, it does not necessarily explain the performance of the experienced pilots. The inexperienced pilots did not possess extensive procedural knowledge to aid them in anticipating upcoming events. Instead, they had to rely on awareness, attentiveness, and recall from the lesson plan procedures or previous scenarios, to anticipate events. In the case of the experienced pilots, it is possible that after comprehending the cue, they recalled the next cue in sequence (level 1) (from long term memory) since they were taught procedurally and developed automaticity for tasks (Endsley & Bolstad, 1994). It is then a question of whether or not the pilots were really projecting (level 3) or rather responding procedurally to the next task or cue in the processing sequence (expected level 1 cues). In this case, situation awareness levels 1 and 3 might, in essence, be the same process (observation or acknowledgment of perceptual cues) which would explain very similar accuracy scores between levels 1 and 3 for each group, as shown in Figure 2. Anticipating may just be a recall exercise in which case, superior memory recall ability would be desired in pilot applicants. This could also explain the experienced pilots' high confidence on level 3 probes.

The Role of Memory in Situation Awareness

The findings on some of the memory-related tests raise a key point. Previous research to date has viewed memory processes as an important component of situation awareness, however little has been explored regarding the relationship between memory

and situation awareness. Sohn and Doane (2004) did however, looked at individual differences and pilots' ability to accommodate situation awareness demands imposed by memory. They found working memory capacity to be more predictive of performance in novices whereas long term memory skills were more predictive of expert pilot performance. This was consistent with skill acquisition theories that suggest cognitive ability plays a greater role in the initial stages of learning than do practical skills (Ackerman, 1988; Sohn & Doane, 2000). Durso and Gronlund (1999) suggested that executive information processes take time to acquire, and as such only experts can rely on long term memory. They further suggest that long-term memory structures cannot be improved in inexperienced operators (Banbury, Croft, Macken & Jones, 2004).

However, the high situation awareness performance group's 100% retention in the SDC delayed recall test demonstrates the ease of transferability to long-term stores even in the case of little to no training (as was the case with the inexperienced pilots that are members of this group. Also, the inexperienced pilots' confidence grew with accuracy.

Another perspective on the role of memory in situation awareness comes from Cass and Parush's (2009) exploratory factor analysis on CogScreen – AE . 73% of the variance was explained involving three factors: 1. visual scanning and tracking speed; 2. selective attention; and, 3. attribute identification. Factor 1 was essentially psychomotor coordination. Competent flying skills including strong tracking ability are essential in order to make room in one's cognitive capacity to selectively attend to perceptual cues in the environment. Perception of cues can then be compared in working memory with those

procedures retained in long-term memory (attribute identification) before anticipating further expected perceptual cues.

A final note on the possible role of memory in situation awareness stems from the pilots' perceptions of situation awareness use during the experimental simulation testing. The question posed was "what percentage of time do you think you used situation awareness versus procedures to respond to the probes." The experienced pilots thought a greater percentage of the probes utilized procedural knowledge rather than situation awareness despite what SME instructors and operators selected during the cognitive task analysis. As explained by the SMEs, Canadian Forces pilots are highly trained on situation awareness during their advanced Sea King training phase. This was evident during the cognitive task analysis walk-throughs. Situation awareness, (perceiving cues, making sense of them and anticipating further cues) are drilled into the pilot students and as such the cues become very intuitive with repetition over time. In essence, the pilots are trained to memorize the process of situation awareness. Although for the most part, they perceived the cues as procedural, it is likely that they memorized the process, and their performance was more indicative of procedural knowledge rather than ongoing and dynamic situation awareness. Conversely, the inexperienced pilots did not have a memorized process to fall back on in responding to questions, which explains why they thought situation awareness was utilized more often than procedures.

Practical Implications

This study is both similar to and different from that of Endsley and Bolstad's (1994) study. Both studies were in search of a predictive selection test measure of

situation awareness and looked at the same situation awareness constructs: spatial, attention, memory, perception and other cognitive functions. Whereas Endsley and Bolstad (1994) pieced together several sub-tests from various sources, to form a test battery, testing it against situation awareness measures, this study looked at an off-the-shelf neuropsychological test to determine a match in those constructs and its predictability. Endsley and Bolstad (1994) found moderate correlations for three of four spatial tests which were deemed to be untrainable during pilot training. Untrainable yet important requirements suggest that selection should assess their availability in the applicant pool. For this reason, they declared that spatial abilities should be tested in selection. Psychomotor skills were also found as an essential component for situation awareness testing (Endsley & Bolstad, 1994). Although a skill rather than a construct, strong tracking skills were also considered essential in reducing cognitive workload, resulting in greater attentiveness to other stimuli in the environment.

In contrast to Endsley and Bolstad's study (1994) which did not exhibit individual differences amongst immediate and delayed memory tests, this study found that the high situation awareness performance group was significantly more accurate than the low situation awareness performance group on the SDC in both immediate and delayed recall conditions. Since working memory and long-term memory are both considered key memory components of situation awareness, these results demonstrate that the SDC can predict situation awareness (memory) performance in pilots. Support for the two hypotheses is found since a good portion of inexperienced pilots were also part of the high situation awareness performance group attesting to individual differences and not

occupationally - related skill or practice. The high situation awareness performance group exhibited higher performance on the DTT previous number alone test conditions thus superior working memory, attribute identification and psychomotor skills compared to the low situation awareness performance group.

The Symbol digit coding immediate and delayed recall sub-tests of the CogScreen – AE battery have demonstrated predictability of situation awareness performance. These sub-tests assess recall, retention, and attribute identification. In light of the results, these sub-tests could be further trialed to assess their predictive qualities for rotary wing pilot situation awareness in a selection setting.

In summary, a selection test for situation awareness should be pursued, particularly, tests of memory (working and long-term memory, attribute identification), and multi-tasking tests (dual tasks). Psychomotor coordination should also be pursued since tracking is a foundational element to aviating. Pilots need to be able to competently fly before they can concentrate on system and environmental cues and upcoming events. With strong psychomotor coordination, pilots increase their cognitive capacity in their workload to be more situationally aware.

Study limitations

There were five main limitations to this study: 1. HelMET simulator, 2. probe randomization issues, 3. limited probes from which to draw, 4. back-to-back scenario testing, and 5. small sample size. Utilizing the HelMET simulator introduced serious limitations since its intended purpose was to train procedures. The scenarios within HelMET were too routine, with no emergencies available. Since HelMET is pre-scripted,

without any possibility for the trainee to control or intervene, it is difficult to keep the pilot as engaged as he would be if he were actually flying the simulator. The routine, repetitive nature of the scenarios resulted in probe randomization issues due to limited probes from which to draw.

Running the scenarios back to back was also problematic. Once cued to the nature of the probes from the first scenario, the pilots quickly realized the types of questions and had insight on what to anticipate, with subsequent scenarios. As such, time and space between scenarios is needed with dramatic differences in content being essential. The final limitation was the sample size. However, a solution to this is difficult since recruiting a sufficient number of pilots of any time is a challenge, given their high operational tempo and numerous military commitments.

Future Research

The promising results of this study, suggest that a larger sample of Sea King pilots should be tested and compared with a comparable number of other rotary wing pilots (such as Griffon pilots). A larger sample would help to increase the power, increase the effect size and decrease alpha, resulting in stronger and more plentiful recommendations. A high-fidelity interactive simulator is also needed; one that requires actual flying and that engages the psychomotor coordination component. By doing so, pilot workload could be increased, and stress possibly induced. Emergency situations should be available to challenge routine procedures and take the otherwise confident pilot out of his comfort zone in assessing his situation awareness. Emergency situations would

also provide more diverse scenarios and a greater variety of probes, mitigating the issue of probe randomization.

The inexperienced pilot sample should possess the “Primary flight training” qualification at a minimum, in order to aptly fly a high-grade simulator. In order to properly randomize the probes, they should not be repeated amongst the various scenarios. With these results and those from the larger study, the CF could then assess these tests in concert with current selection protocols to see if the CogScreen - AE provides incremental validity above and beyond current measures, with an over-arching goal of improving current Rotary Wing pilot selection.

As a subsequent study, examination of the other two pilot streams (fast air and multi-engine) should also be studied to assess if there are significant situation awareness differences between the three streams. If these results show predictability of situation awareness with the CogScreen – AE based on a larger sample and comparison streams, then, the CF could test the CogScreen – AE on other operational occupations such as the Combat Arms and Naval occupations.

Another possible study should examine situation awareness performance and age. Canada is the only known NATO country to not have an age restriction on pilot enrolment. (The Canadian Human Rights Act does not allow age discrimination in selection). However, if age is reducing situation awareness and effectiveness due to slower reaction times then rigorous, empirical evidence would be necessary in order to change the selection protocols and policies. Since CogScreen – AE is normed by age groups; it remains a viable instrument for this purpose. A further study could look at how workload moderates situation awareness performance by examining NASA TLX scores

in relation to situation awareness performance. Although the number of significant relationships between the situation awareness groups and the CogScreen – AE are few, a larger sample might increase the power of the study and possibly result in more significant tests adding further support towards the hypotheses and further consideration of the CogScreen – AE as a pilot situation awareness predictor.

Significance of this study

This is the first known study to assess an off-the-shelf aerospace cognitive test battery as a possible situation awareness predictor for use in pilot selection. The CogScreen – AE demonstrated that it can predict individual differences in terms of memory. The Symbol Digit Coding test and the Dual Task Tracking test could be used in selection to assess recall, retention, working memory, attribute identification and motor skills which are constructs associated with situation awareness.

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Appendices

Appendix A: CogScreen – AE Sub-tests and Constructs²*Backward Digit Span (BDS)*

This sub-test provides the sequential visual presentation of three to six digits at a time. The respondent must recall the sequence of visually presented digits, but in reverse order. Two sequences of three digits are followed by two sequences of four, five, and six digits. This subtest purports to measure visual attention, working memory and verbo-sequential processing.

Math (MAT)

This sub-test is comprised of five traditional multi-step math problems (approximately Gr. 10 level of difficulty). The candidate reads the problems and selects the best answer from three choices (without the aid of a calculator or paper). This sub-test requires computational math skills, attention, concentration, working memory, reading comprehension, and logical reasoning.

Visual Sequence Comparison (VSC)

This sub-test presents two alpha-numeric strings that resemble license plates, with one string on the left side and one string on the right side of the computer screen. The respondent selects SAME or DIFFERENT for each pair, with the length of strings varying from four to eight items. Half of the 20 items are the same and half of them are

² Re-printed with permission (Kay, 1995).

different, presented in random order. This sub-test purports to measure visual attention, working memory, verbal-sequential processing and visual-perceptual speed.

Symbol Digit Coding (SDC)

Similar to the WAIS – R Digit Symbol sub-test, (Wechsler, 1981), this is a symbol substitution test. Six symbol-digit pairs are displayed continuously throughout the test near the top of the screen. The respondent must remember the symbol-digit pairs for a subsequent memory test. In the center of the screen, a line of symbols in random order is presented with blank spaces directly beneath each symbol. The respondent selects the associated digit for each symbol. After each response, a new row appears. This sub-test purports to measure: attention, working memory and speed of information processing, attribute identification.

SDC immediate recall task.

This sub-test follows immediately after the 90-second SDC learning task above. In this task, the respondent is presented with six symbols, presented in random order. The respondent must recall the corresponding digits. This test purports to measure immediate visual-paired associate memory.

SDC delayed recall task.

This sub-test is identical to the immediate recall task except it is presented after the Pathfinder subtest (following a 20-30 minute delay) with other sub-tests administered in between. This test purports to measure delayed, visual paired-associate memory. A comparison of immediate and delayed recall provides a measure of retention.

Matching-to-Sample (MTS)

This sub-test presents a four-by-four grid of filled and empty cells. After a brief delay, two grids are presented on each side of the screen. One patterned grid is the same as the original pattern grid shown previously; the other is different from the original pattern grid, but only by one cell out of 16. The respondent's task is to discriminate and choose the pattern grid that matches the original grid pattern. 20 trials are presented with equal number of correct matches on the left side of the screen as on the right side of the screen. This sub-test purports to measure visual-perceptual speed, spatial processing, and visual working memory.

Manikin (MAN)

This sub-test represents a male figure that is right-side-up, up-side-down, facing forward, or facing backward. The figure is holding a flag. The respondent must determine whether the figure is holding the flag in his left or right hand. 20 trials are presented with equal number of left-hand and right-hand presentations.

Divided Attention (DAT)

This subtest has two components: a visual monitoring task (only) and the simultaneous presentation of the visual monitoring task and the previously described visual sequence comparison (of license plates).

DAT indicator alone task.

The first DAT test is a visual monitoring test. In this task, the respondent watches a horizontal cursor move vertically up and down, within a circle that is divided into central, upper and lower sections. When the cursor crosses into either the upper or lower areas, the respondents' task is to press a button marked "CENTER". In this particular

task, DAT Indicator Alone Premature Responses are also recorded i.e. the number of premature hits made on the “CENTER” button. In addition to visual monitoring, this test purports to measure impulsivity and vigilance.

DAT indicator dual task.

In the second DAT task, the Visual Sequence Comparison (license plates) task is presented simultaneously with the visual monitoring task just completed. Again, premature centering responses are also collected. When the two tasks are tested simultaneously, the sub-test measures divided attention, working memory, visual-motor, and visual-perceptual speed. A comparison between the two tasks and premature responses, provide indications of multi-tasking capacity and impulsivity.

Auditory Sequence Comparison (ASC)

This sub-test provides a sequential series of four to eight tones, of varying pitch (e.g. boop, bee, bee boop). Immediately after the first sequence is presented, a second is played. The respondent must decide if the tone sequences are the SAME or DIFFERENT. This sub-test purports to measures auditory attention, working memory and sound pattern discrimination.

Pathfinder (PF)

This sub-test provides a number or a letter displayed in the center of the screen. The respondent must select one of the four quadrants containing the next number or letter and tap on the middle of the letter or number. Three of four quadrants containing numbers of letters are updated after each response. The three sub-tests are: Pathfinder number (PFN) (number sequencing) Pathfinder letter (PFL) (letter sequencing), Pathfinder combined (PFC) (requires alternating number and letter sequencing). Besides

sequencing, Pathfinder measures the ability to apply an organizing principle, immediate memory, motor coordination, visual scanning, and the ability to shift mental set.

Shifting Attention (SAT)

The object of this test is to alter responses depending upon changing rules. The respondent's role is to select one of four boxes presented simultaneously, following the rules provided. The Border color condition (SATAC) is the first rule. It requires the respondent to select a box based on the color of its border. Arrow Direction (SATAD) is the second rule. It requires the respondent to select a box based on the direction of the arrow. Arrow Color (SATAC) is the third rule. It requires the respondent to match the color of the arrow.

After learning the three responses or rules, the Instruction condition (SATIN) is next. The participant is flashed an instruction on the screen identifying the active rule. The respondent then applies that rule to select the appropriate box. The rule changes frequently and requires the participant to apply new rules, identify attributes and utilize cognitive flexibility. In the fifth and final condition, Discovery (SATDI), the participant's task is to discover the active rule and then apply it. The active rule changes after a variable number of correct responses and without warning. This condition requires trial-and-error to deduct the active rule and apply it. This condition also requires new rule application, attribute identification, sustained attention, switching, cognitive flexibility, deductive reasoning, working memory and monitors vulnerability to response interference, and perseverative tendencies.

In addition to the normal measurements taken, measurements are also collected on the number of discovery rule shifts completed, the number of failures to maintain set

(rule), the number of non-conceptual responses, and perseverative errors (i.e. repeat a response after the cessation of the original stimulus). The SAT purports to measure concept formation (attribute identification), mental flexibility, sustained attention, deductive reasoning, rule flexibility, vulnerability to response interference, working memory, application of novel rules, visual scanning, choice visual reaction time and perseverative tendencies.

Dual Task Tracking (DTT)

In this test, two tasks are presented independently followed by a simultaneous exposure for a measure of divided attention and multi-tasking capability.

DTT tracking alone (DTTA).

This is a visual-motor tracking test that requires the respondent to use the side arrow buttons on the computer keyboard to maintain a cursor in the center of the screen on what looks like a see-saw balancing on a fulcrum. Without active tracking effort, the cursor disappears off the screen and is counted as a “boundary hit”. Response measures include mean absolute tracking error and the number of boundary hits.

DTT previous number alone (DTTPNA).

The second task is a previous number exercise in which the respondent is shown a 1, 2, or 3 that is replaced with a 1, 2, or 3. The respondent must recall the previous number shown and select that number while simultaneously encoding the current number for the next stimulus presentation.

DTT dual task (DTTPD).

This sub-test combines the tracking task with the previous number task. Tracking dual errors and tracking dual boundary hits are measured in addition to the normal speed,

accuracy and throughput. DTT purports to measure sustained attention, visual-motor tracking, divided attention, and working memory.

Appendix B: CogScreen – AE Measures³

Response Time

Reaction times are calculated for the following sub-tests: Math, Visual Sequence Comparison, Matching-to-Sample, Manikin, Divided Attention Sequence Comparison (the alone and dual speed conditions), Auditory Sequence Comparison, Pathfinder number, letter and combined speed, Shifting Attention Arrow direction, Arrow color, Instruction and Discovery speeds, Dual Task Tracking previous number alone speed, Dual Task Tracking previous number dual speed, Dual Task Tracking alone error, Dual Task Tracking dual error.

The score represents the median reaction time on correct trials of the CogScreen - AE tasks. The median time is calculated, in lieu of the mean, to reduce the impact of outlier response times for all sub-tests with the exception of the Dual Task Tracking alone error and the Dual Task Tracking dual error. These two sub-tests are expressed as the average absolute deviation of the tracking cursor from the center target point in pixel units. Every 100 milliseconds, the program records the location of the tracking cursor relative to the center point. These tracking measures are obtained from the mean absolute values of the 600 cursor location scores recorded during the 60-second trials.

Response Accuracy

Response accuracy is calculated as the percentage of correct responses to the total number of items that were administered for the following sub-tests: Backward Digit

³ Re-printed with permission (Kay, 1995).

Span; Math; Symbol Digit Coding, including immediate and delayed recall accuracy; Matching to Sample; Manikin; Divided Attention Sequence Comparison; Auditory Sequence Comparison; Pathfinder number, letter and combined; Shifting Attention Arrow direction, Arrow color, Instruction and Discovery accuracy; Dual Task Tracking Previous number alone, and Dual accuracy.

$$\text{Accuracy} = (\text{Number of Correct Responses} / \text{Total number of items}) \times 100$$

Thruput Measures⁴

The thruput measures express response efficiency and reflect the number of correct responses-per-minute. They are captured for the following sub-tests: Math; Visual Sequence Comparison; Symbol Digit Coding; Matching-to Sample; Manikin; Divided Attention Sequence Comparison; Auditory Sequence Comparison; Pathfinder number, letter, and combined; Shifting Attention Arrow direction, Arrow color, Instruction and Discovery, Dual Task Tracking Previous number alone and Dual conditions. The formula used to calculate thruput is:

$$\text{Thruput} = \frac{(\text{Accuracy}/100) \times 60 \text{ seconds}}{\text{Median Response Time for Correct Trials}}$$

Although thruput scores provide less information than individual speed and accuracy, they provide useful measures of efficiency of mental processing. However it should be noted, normal populations typically produce thruput scores with high levels of inter-correlation making interpretation of factor loadings difficult (Kay, 1995).

Process Measures

⁴ The term “thruput” is spelled and written as it appears in the CogScreen – AE manual (Kay, 1995).

Several sub-tests also generate process measures that capture important qualitative and process-oriented performance characteristics. These include: Divided Attention indicator alone premature responses, Divided Attention indicator dual premature responses, Pathfinder number, letter and combined coordination; Shifting Attention Discovery rule shifts completed, failures to maintain set, discovery non-conceptual responses, perseverative errors; dual task tracking alone and dual boundary hits.

Appendix C: HelMET Scenarios

Appendix D: Subject Matter Expert Informed Consent

Subject Matter Expert Informed Consent

The purpose of this informed consent is to ensure that you understand the purpose of the study and the nature of your involvement. The informed consent has to provide sufficient information such that you have the opportunity to determine whether or not you wish to participate in this study.

Study Title: Assessing CogScreen – AE as a Potential Pilot Selection Test.

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Should you have any ethical concerns about this study, please contact Dr. Monique Senechal (Chair, Carleton University Ethics Committee for Psychological Research, 613-520-2600, ext. 1155) or Dr. Janet Mantler, (Chair, Department of Psychology, Carleton University, 613-520-2600, ext. 4173).

Purpose and Task Requirements: The purpose of this study is to assess the appropriateness of a potential Rotary Wing selection test, namely the CogScreen – Aerospace (AE). To do so, we must understand the cognitive demands that are placed upon Rotary Wing (RW) pilots during a complex operational task namely, a deck landing, as a means of improving pilot selection tests. In doing so, you will be asked to assist as a subject matter expert throughout this study. Your involvement will be required for the first phase namely, the Cognitive Task Analysis (CTA). You may also be contacted during the analysis phase to respond to researcher questions about the deck landing tasks. For the CTA, you will be asked to demonstrate how to conduct Sea King deck landings through use of the HelMET simulator and four scenarios. You may be asked to describe each of the critical way points and steps, (e.g. what you see and hear, what that information means to you and what it compels you to do next). The simulator will be paused throughout each scenario to fully explore each sub-task. Together with other SME's you will be asked to assist in designing related probes and appropriate responses for each of the tasks involved and strategically plan the best place to freeze the simulator to ask the probes to participants. Time permitting you may also appropriateness of probes, responses and freeze points.

Potential Risk and Discomfort: This study is non-invasive but poses minimal risk of simulator sickness to participants. If you feel sick, anxious or uncomfortable about your involvement in this study, please bring your concerns to the researcher's attention. Any simulator sickness must be reported to Wing Operations in that it may impact flight operations scheduling.

In accordance with 1 Canadian Air Division Headquarters Order Volume 2-2 007 page 3/17 paragraph 9, *“Any aircrew who has conducted operations in the virtual environment of the HelMET shall be restricted from all flying duties for a period of 12 hours following the session”*. However, given that simulation will end by 1630 hrs daily, this is not expected to limit your availability for further simulation or flight operations the following day.

Anonymity/Confidentiality: The data collected in this experiment are confidential. All data collected are encoded to afford you anonymity. The coded data will only be available to the researchers involved in this study. Your simulation(s) will be videotaped to assist in recollecting the events and capturing data. However your name or personal information will not be associated with the recording.

Right to Withdraw: Your participation in this study is entirely voluntary. At any point during the study, you have the right to not answer certain questions or to withdraw with no penalty whatsoever.

I have read the above description of *Assessing CogScreen – AE as a Potential Pilot Selection Test* and understand the conditions of my participation. My signature indicates that I agree to participate in the study, and this in no way constitutes a waiver of my rights.

Full Name (please print): _____

Participant Signature: _____

Date: _____

Researcher Signature: _____

Date: _____

Appendix E: Demographics Questionnaire

DEMOGRAPHIC QUESTIONNAIRE

Please complete the following information to so I can better understand your Sea King experience to date. Completion of any question is considered voluntary.

1. How many years has it been since you have successfully completed OTU training?
 - a. I have not completed my OTU training
 - b. 1 – 2 years
 - c. 3 - 5 years
 - d. 6 - 10 years
 - e. more than 10 years

2. In which of the following capacities have you served as a CH-124 Sea King Pilot
 - a. Instructor
 - b. Operational CH-124 pilot
 - c. Both
 - d. Neither

3. Are you qualified as an Aircraft Captain?
 - a. Yes
 - b. No (skip to #5)

If so, how many hours have you logged?

4. If you answered yes to #3, are you also qualified as a Crew Commander?
 - a. Yes
 - b. No

If so, how many years/months have you served as a Crew Commander?

5. When was the last time you flew in an operational capacity?
 - a. I have not flown operationally

- b. less than 1 year ago
- c. 1 - 2 years ago
- d. 3 - 5 years ago
- e. 6 or more years ago

6. How many live deck landings have you successfully completed throughout your career as a Sea King pilot?

- a. None
- b. 100-500
- c. 501-1000
- d. 1001-2000
- e. 2001-3000
- f. more than 3000

7. Have you already flown a Sea King today?

- a. Yes
- b. No

If so, for how long?

8. Are you fit to fly right now IAW 1 Canadian Air Division Orders?

- a. Yes
- b. No

Appendix F: Cognitive Working Definitions

SPATIAL

Mental Rotation	Manipulation of images in whole, or in part by parsing the image into units and mentally rotating the individual pieces sequentially.
Spatial Orientation	Ability to maintain orientation (direction) while moving through space or the ability to point to unseen goals and draw maps.

ATTENTION

Divided Attention	Paying attention to a number of things simultaneously; depends upon three factors (practice, difficulty, and type of task).
Visual Monitoring	Maintaining regular surveillance over a task.
Selective Attention	The ability to focus on one message and miss or ignore all others.
Sustained Attention/Vigilance	Ongoing alert watchfulness for the appearance of an unpredictable stimulus, which may be sensed through any of the sensory modalities.
Switching Attention	Moving the focus of attention from one entity to another.

MEMORY

Long-term memory	A memory mechanism that can hold large amounts of information for long periods of time.
Retention	The maintenance of memories after their initial encoding.
Working Memory (WM)	Holds 5-9 items at a time; information is held for 15 – 30 seconds. Rehearsal or other mnemonic strategies can help retain it in LTM.

PERCEPTION

Information processing speed	Rate of encoding, decoding, storing and retrieving information.
Visual processing	The sequence of steps that information takes as it flows from visual sensors to cognitive processing.
Sequencing	The ability to order information or actions to achieve a goal.

**OTHER COGNITIVE
FUNCTIONS**

Comprehension	Cognitive processes used for understanding text as a whole and thereby making sense of what is read.
Deductive reasoning	A process by which an individual tries to draw a logically certain and specific conclusion from the propositions on which it is based.
Computational skills	Indexed by the accuracy and speed with which simple arithmetic problems are solved as well as by the solution procedure that is used.
Cognitive flexibility	An executive function; the ability to switch behavioural response according to the context of the situation. Allows switching of attention set.

PSYCHOMOTOR

Motor coordination	A combination of body movements such as spatial direction and force parameters that result in intended actions. Involves the integration of processes ranging from how muscles interact with the skeletal system to neural processes controlling them both in the spine and the brain.
Visual motor tracking	Hand-eye coordination.

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
Ship's Numbers Co-pilot for first half of scenario.	00:30	Where are winds in relation to ship?	On nose <i>Cognitively deduced. Told where winds are. Look up to confirm ship is where it should be.</i>	II	SPATIAL	Spatial orientation	MTS, BDS
						Mental rotation	MAN
					ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
	00:30	What are the true winds?	000 at 15	I	ATTENTION	Selective attention	SAT, DAT, DTT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC,

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
							MTS
	00:30	What are the relative winds?	000 at 30	I	ATTENTION	Selective attention	SAT, DAT, DTT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
	00:30	What are your altitude and speed?	200 Ft and 90 knots	I	ATTENTION	Visual monitoring	DAT
			<i>Visually scan out window and cross check/monitor against instrument panel readings.</i>		MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Information processing speed	SDC, MTS
		Is it a green or red	Neither (180 behind	II	SPATIAL	Spatial orientation	MTS, BDS

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
	00:30	approach?	ship) <i>Told over radio with numbers</i>			Mental rotation	MAN
					ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
A/C Position prior to	00:35	Do you know where you are?	2.25 NM <i>Instrument panel</i>	III	ATTENTION	Visual monitoring	DAT
					MEMORY	Long-term memory	SDC

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
FAF					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Information processing speed	SDC, MTS
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
Control	00:41	Can SAC pass control to the LSO at this point?	No. <i>Radio check would suggest yes but deductive reasoning would suggest no - i.e. the ship does not yet have a visual of helo since the helo does not have a visual of the</i>	III	ATTENTION	Selective attention	SAT, DAT, DTT
						Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT,

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
			<i>ship</i>				SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
At the FAF	1 03 (At FAF)	What's the next altitude report?	150 Ft (50 ft above the minimum descent altitude (100 Ft)	III	SPATIAL	Spatial processing	MTS, BDS
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
			<i>Learned and retained through training/experience</i>			Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
						Information processing speed	SDC, MTS

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
Descent inside the FAF	1 20	What should you anticipate prior to establishing the 100 Ft altitude?	RAWS tone	III	SPATIAL	Spatial processing	MTS, BDS
			<i>An auditory beep indicating that descent is approaching a very low level</i>		ATTENTION	Selective attention	SAT, DAT, DTT
						Visual monitoring	DAT
						MEMORY	Long-term memory
					PERCEPTION	Information processing speed	SDC, MTS
After RAWS and Before 1 NM	2 13	What happens at 1 NM?	Slow to your creep speed	III	ATTENTION	Selective attention	SAT, DAT, DTT
			<i>Based on knowledge gained through training</i>		MEMORY	Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Information processing speed	SDC, MTS

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
At 1 NM	2 13	What will be your creep speed?	60 knots (30 knots relative wind speed + 30 knots) <i>Cognitively deduced after recalling relative winds and adding that information to the known calculation for creep speed</i>	III	ATTENTION	Divided attention	DAT, DTT
						Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					OTHER COGNITIVE FUNCTIONS	Computational math skills	MAT
						Deductive reasoning	SAT, MAT
At 1 NM	2 39	To what distance can you close on the ship at this point?	½ NM only <i>Given by SAC through transmission</i>	II	ATTENTION	Visual monitoring	DAT
						Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Information processing speed	SDC, MTS
					OTHER COGNITIVE FUNCTIONS	Deductive Reasoning	SAT, MAT
RadHaz	2:52	What is current RadHaz state?	RadHaz safe port. <i>Given by SAC through transmission.</i>	I	ATTENTION	Selective attention	SAT, DAT, DTT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
	2:52	Can you fly to the right – why?	No. RadHaz not safe starboard side.	II	ATTENTION	Selective attention	SAT, DAT, DTT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
			<i>Cognitively deduced based on previously given information.</i>		OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
Control	3:00	Who is the control agency – SAC or LSO?	SAC <i>Recalled from working memory.</i>	II	ATTENTION MEMORY	Selective attention Working memory	SAT, DAT, DTT ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
Landing Type between ½ NM and Delta Hover Astern <i>(Participant takes over flying duty)</i>	3:19	What kind of landing are you expecting to conduct?	Not sure yet. It will depend upon pitch/roll (not given yet). <i>Recalled from knowledge gained through training.</i>	III	ATTENTION MEMORY PERCEPTION	Selective attention *Sustained attention Long-term memory Visual processing	SAT, DAT, DTT SAT SDC VSC, MTS, BDS, DAT, SAT, DTT, PF

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
<i>for landing)</i>					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
Landing Type	3:59	What type of landing can you anticipate – free deck or haul down	Haul down <i>Visual cue available (i.e. man on deck.</i>	III	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
After haul down confirmed	4.44	Is the deck ready for a haul down?	Yes <i>Visual cues - deck member on deck, safety bar has been removed, and the cable is paid out</i>	II	ATTENTION	Divided attention *Sustained attention	DAT, DTT SAT
					MEMORY	Long-term memory	SDC
					PERCEPTION	Visual processing Information processing speed	VSC, MTS, BDS, DAT, SAT, DTT, PF SDC, MTS
					OTHER COGNITIVE	Deductive reasoning	SAT, MAT

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
					FUNCTIONS		
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						Visual motor tracking	DTT
Moving across deck	5 01	As the flying pilot, what are you going to request your crew to do now?	Lower the gear (L/H co-pilot), Lower the messenger (AES Op). <i>Based on knowledge gained through training</i>	III	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
						Information processing speed	SDC, MTS
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
						*Visual motor tracking	DTT
Hook-up	5:33	What will be the max tension?	1400 gas, 16000 aircraft weight = 3000 lbs (+/- 300 – 400) is max tension. <i>Cognitively deduced by applying knowledge of the maximum tension calculation, recalling the aircraft base weight from long-term memory, plus any additional cargo weight and fuel load attained through pre-briefings.</i>	III	ATTENTION	Divided attention *Sustained attention	DAT, DTT SAT
					MEMORY	Working memory Long-term memory Computational Math	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS SDC SDC, SAT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive Reasoning	MAT SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination *Visual motor tracking	PF DTT

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
Trafficators	5:39	Why are the traffic indicators amber?	Means stop lowering the messenger.	II	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
			<i>Recalled from knowledge of haul down procedure training.</i>	I	MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
						Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					PSYCHOMOTOR COORDINATION	Information processing speed	SDC, MTS
						*Motor coordination	PF
Hover Tension	6:33	Can you request hover tension?	No – haul down cable is not locked yet	III	ATTENTION	*Visual motor tracking	DTT
						Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC,

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
			<i>Evident from the haul down panel/lights.</i>				PF, BDS, MAT, SDC, MTS
					PERCEPTION	Long-term memory	SDC
						Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
						Information processing speed	SDC, MTS
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
	6:33	Where is the messenger right now?	Raising	II	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC,

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
			Visual scan, recalling steps in the process that have occurred.		PERCEPTION	Visual processing	PF, BDS, MAT, SDC, MTS
						Sequence processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					PSYCHOMOTOR COORDINATION	*Motor coordination	VSC, BDS, DAT
						*Visual motor tracking	PF
							DTT
Cable Tension	6:37	How much tension is on the cable?	Zero tension – <i>Cognitively deduced from “3 green” lights on panel and the two green trafficators on hangar. Also there has not been a request for hover tension yet.</i>	III	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
						Sequence processing	VSC, BDS, DAT
					OTHER COGNITIVE FUNCTIONS	Information processing speed	SDC, MTS
						Deductive reasoning	SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT

Appendix G: Cognitive Task Analysis Summary Scenario B

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA-Related Constructs	Sub-Constructs	Related CogScreen - AE Sub-tests
Pitch & Roll	8.28	Is the pitch and roll of the sip conducive to a haul down landing?	Yes – within normal limits.	II	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
			<i>Based on info gained through transmission on pitch and roll in addition to the instrument panel readings. Also involves knowledge on what is acceptable for a haul down landing (based on training).</i>		MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	SDC, SAT, PF
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
Ship's Numbers Co-pilot for first half of scenario	00:35	Where are winds in relation to the ship?	On the nose <i>Cognitively deduced. SAC briefs on winds. Pilot looks up to confirm ship is where it should be.</i>	II	SPATIAL	Spatial orientation	MTS
						Mental rotation	MAN
					ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
	00:35	What are the true winds?	000 at 10	I	ATTENTION	Selective attention	SAT, DAT, DTT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
	00 35	What are the relative winds?	000 at 20	I	ATTENTION MEMORY	Selective attention Working memory	SAT, DAT, DTT ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
	00 35	What are your altitude and speed?	200 Ft and 90 knots <i>Visually scan out window and cross check/monitor against panel instrument readings</i>	I	ATTENTION MEMORY PERCEPTION	Visual monitoring Working memory Visual processing Information processing speed	DAT ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS VSC, MTS, BDS, DAT, SAT, DTT, PF SDC, MTS
	00.35	Is this a green or red approach?	Green <i>Recall SAC numbers, confirmed through deductive reasoning, based on</i>	I	SPATIAL ATTENTION	Spatial orientation Mental rotation Visual monitoring	MTS MAN DAT

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
			<i>ship's position, winds.</i>		MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
Control	00:40	Can SAC pass control to the LSO at this point?	Yes <i>Cognitively deduced since radio check has been done and LSO has visual of ship.</i>	II	ATTENTION	Selective attention	SAT, DAT, DTT
						Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
						Sequence Processing	VSC, BDS, DAT
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
At the FAF 200 Ft and 2 NM	1:16	What's the next altitude report?	150 Ft (50 Ft above min descent altitude (100 Ft). <i>Learned and retained through training/experience.</i>	III	MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Sequence processing	VSC, BDS, DAT
						Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Information processing speed	SDC, MTS
Descent inside the	1:19	What can you anticipate prior to	RAWS audio tone.	III	ATTENTION	Selective attention	SAT, DAT, DTT

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
FAF		establishing the 100 ft altitude?	<i>An auditory beep indicates that a descent is approaching a critically low level</i>			Visual monitoring	DAT
					MEMORY	Long-term memory	SDC
					PERCEPTION	Information processing speed	SDC, MTS
1 NM	1 35	Are you lined up for a green or red approach?	Green	II	SPATIAL	Spatial orientation	MTS, BDS
						Mental rotation	MAN
			<i>Cognitively conduct spatial orientation, recall what SAC told for approach, monitor position in relation</i>		ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
	1 35	At 1 NM, what will be your creep	50 knots (20 knots relative wind speed	III	ATTENTION	Divided attention	DAT, DTT

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
		speed?	+ 30 knots).			Visual monitoring	DAT
			<i>Cognitively deduced after recalling relative winds and adding that info to the known calculation for creep speed</i>		MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					OTHER COGNITIVE FUNCTIONS	Long-term memory Computational math skills	SDC MAT
						Deductive reasoning	SAT, MAT
100 Ft and 75 NM	2 26	To what distance can you close the ship?	½ NM only	II	ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
			<i>Given by SAC through transmission</i>			Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Information processing speed	SDC, MTS
						Deductive reasoning	SAT, MAT

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
RadHaz	2 30	What is the current RadHaz state?	RadHaz not safe. <i>Recalled what was briefed by SAC</i>	I	ATTENTION MEMORY	Selective attention Working memory	SAT, DAT, DTT ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
	2.30	Can you proceed inside ½ NM – why or why not?	No – not RadHaz safe yet. <i>Cognitively deduced based on previous information (numbers)</i>	III	ATTENTION	Selective attention	SAT, DAT, DTT
MEMORY					Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS	
OTHER COGNITIVE FUNCTIONS					Deductive reasoning	SAT, MAT	
Control	3:00	Who’s the control agency – SAC or	LSO	II	ATTENTION	Selective attention	SAT, DAT, DTT
		LSO?	<i>Recall from working memory</i>		MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
Ship’s Classification	3:39	What classification of warship is this?	CPF (frigate, city class/Halifax class)	II	MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
			<i>Based on visual scanning and attribute identification of environment, confirming it’s the right ship.</i>			Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
Landing Type	4:08	What type of landing can you anticipate – free deck or haul down?	Free deck – no man on deck.	III	ATTENTION	Divided attention	DAT, DTT
Participant takes over flying for landing			<i>Based on knowledge gained through training and visual scanning.</i>			*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
			PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF		

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
Moving across deck	4:51	As the flying pilot, what are you going to request from your crew?	To lower the landing gear (co-pilot). <i>Based on knowledge gained through training.</i>	III	OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
					ATTENTION	Divided attention	DAT, DTT
					MEMORY	*Sustained attention	SAT
						Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Long-term memory	SDC
						Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
						Information processing speed	SDC, MTS

Appendix H: Cognitive Task Analysis Summary Scenario C

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
On landing	5:57	Can ship maneuver right now?	No – tail probe not down. <i>Auditory attention (LSO orders) and instrument panel lights</i>	III	PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
					ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
					*Visual monitor tracking	DTT	

*Sustained attention and psychomotor coordination is required when the pilot is actually flying

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
Ship's Numbers Co-pilots for first half of scenario.	00:30	Where are winds in relation to ship?	On nose. <i>Cognitively deduced. SAC briefs numbers. Pilot looks up to confirm ship's location and where it should be.</i>	II	SPATIAL	Spatial orientation	MTS, BDS
						Mental rotation	MAN
					ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
	00:30	What are the true winds?	000 at 10	I	ATTENTION	Selective attention	SAT, DAT, DTT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS,

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS MAT, SDC, MTS
	00:30	What are the relative winds?	000 at 20	I	ATTENTION	Selective attention	SAT, DAT, DTT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
	00:30	What are your altitude and speed	200 Ft and 90 NM. <i>Visually scan out window and cross-check/monitor against instrument panel readings.</i>	I	ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
	00:30	Is this a green or red approach?	Red <i>Recall SAC numbers;</i>	I	SPATIAL	Spatial orientation	MTS, BDS
						Mental rotation	MAN

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
			<i>confirmed through deductive reasoning, based on ship's position, winds.</i>		ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
Control	00:43	If LSO is visual, can SAC pass control to the LSO at this point?	Yes. If the LSO can see the helo. <i>Cognitively deduced based on whether the help can see the ship.</i>	II	ATTENTION	Selective attention	SAT, DAT, DTT
						Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
At the FAF	1:17	What is the next altitude report?	150 Ft (50 Ft above min descent altitude (100 Ft).	III	MEMORY	Working Memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
200 Ft and 2 NM						Long-term memory	SDC
			<i>Learned and retained through training/experience</i>		PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
						Sequence processing Information processing speed	VSC, BDS, DAT SDC, MTS
Descent inside the FAF	1:21	What can you anticipate prior to establishing the 100 Ft altitude?	RAWS tone. <i>An auditory beep indicating that descent is approach a critically low level.</i>	III	ATTENTION MEMORY PERCEPTION	Selective attention Visual monitoring Long-term memory Sequence processing	SAT, DAT, DTT DAT SDC VSC, BDS, DAT
1 NM	1:41	Are you lined up for a green or red approach?	Red <i>Based on spatial orientation and</i>	II	SPATIAL	Spatial orientation Mental rotation	MTS, BDS MAN

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
			<i>mental rotation (depending on current position). Confirmed through recollection of numbers given by SAC.</i>		ATTENTION	Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
	1:41	At 1 NM, what will be your creep speed?	50 knots (20 knots relative wind speed + 30 knots). <i>Cognitively deduced after recalling relative</i>	III	ATTENTION	Divided attention	DAT, DTT
						Visual monitoring	DAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS,

Appendix I: Cognitive Task Analysis Summary Scenario D

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Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
						processing speed	SDC, MTS
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
RadHaz	2:55	What is current RadHaz state?	RadHaz safe port. <i>Given by SAC through radio transmission.</i>	I	ATTENTION MEMORY	Selective attention Working memory	SAT, DAT, DTT ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
	2:55	Can you proceed inside ½ NM – why or why not?	Yes - but can only proceed on left side, due to RadHaz safe port. <i>Application of rule, using recall of RadHaz clearance. Based on memory of what SAC briefed. Learned.</i>	III	ATTENTION MEMORY OTHER COGNITIVE FUNCTIONS	Selective attention Working memory Long-term memory Deductive reasoning	SAT, DAT, DTT ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS SDC SAT, MAT

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
	2:55	Who is the control agency – SAC or LSO?	SAC <i>Paying attention and deciphering voices, following conversations over radio and keeping track.</i>	II	ATTENTION MEMORY	Selective attention Working memory	SAT, DAT, DTT ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
Between 1/2 NM and Delta Hover Astern (Landing type) <i>Participant flies landing.</i>	3:24	What kind of landing are you expecting to conduct – free deck or haul down?	Not sure yet – either – depending upon pitch/roll (missing info). <i>Recalled from knowledge gained through training.</i>	III	ATTENTION MEMORY PERCEPTION OTHER COGNITIVE	Selective attention Working memory Long-term memory Visual processing Deductive reasoning	SAT, DAT, DTT ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS SDC VSC, MTS, BDS, DAT, SAT, DTT, PF SAT, MAT

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
					FUNCTIONS		
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
Landing type	3:46	What type of landing can you anticipate – free deck or haul down	Haul down. <i>Visual cue available (man on deck).</i>	III	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE	Deductive Reasoning	SAT, MAT

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
					FUNCTIONS		
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
Moving across the ship	4:51	As flying pilot, what are you going to request your crew to do now? Then what?	Lower the gear (co- pilot); lower the messenger (AES Op). <i>Based on knowledge gained through training.</i>	III	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
						Information processing speed	SDC, MTS
						PSYCHOMOTOR	*Motor

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
					COORDINATION	coordination	PF
						*Visual motor tracking	DTT
	5:28	Why are the trafficators amber?	Means stop lowering the messenger. <i>Recalled from knowledge of haul down procedure training.</i>	II	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Information processing speed	SDC, MTS
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
						*Visual motor tracking	DTT
Hover Tension	6:06	Can you request hover tension?	No – Haul down cable is not locked yet – evident from haul down panel. <i>Evident from haul down panel/lights.</i>	III	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS SDC
					PERCEPTION	Long-term memory	VSC, MTS, BDS,
						Visual processing	DAT, SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
						Information processing speed	SDC, MTS
					OTHER COGNITIVE	Deductive reasoning	SAT, MAT

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
					FUNCTIONS		
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
	6:06	Where is the messenger right now?	Raising <i>Visual scan, recalling steps in process that have occurred and anticipating what's next.</i>	II	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Sequence processing	VSC, BDS, DAT
					PSYCHOMOTOR	*Motor	PF

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
					COORDINATION	coordination *Visual motor tracking	DTT
	6 18	What will be the max tension?	900 pounds Cognitively deduced	III	ATTENTION	Divided attention *Sustained attention	DAT, DTT SAT
					MEMORY	Working memory Visual processing	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS VSC, MTS, BDS, DAT, SAT, DTT, PF
						Information processing speed	SDC, MTS
					OTHER COGNITIVE FUNCTIONS	Computational math	MAT

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
						Deductive reasoning	SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DTT
Cable Tension	6:20	How much tension is on the cable?	Zero tension <i>(inferred from 3 green on panel and the two green trafficators on hangar)</i>	II	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS
			<i>Cognitively deduced from 3 green lights on panel and the two green trafficators on hangar. Also there has not been a request for</i>		PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
						Sequence	VSC, BDS, DAT

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
			<i>hover tension yet.</i>			processing	
						Information processing speed	SDC, MTS
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						*Visual motor tracking	DAT
Maneuver	7:05	Can ship maneuver right now?	No – tail probe not down. <i>Visual scan of the instrument panel lights and recalling the steps involved.</i>	III	ATTENTION	Divided attention	DAT, DTT
						*Sustained attention	SAT
					MEMORY	Working memory	ASC, DAT, SAT, VSC, PF, BDS, MAT, SDC, MTS

Appendix I: Cognitive Task Analysis Summary Scenario D

EVENT (CWP)	TIMING	PROBE	ANSWER	SA LEVEL	SA – RELATED CONSTRUCTS	SA SUB- CONSTRUCTS	RELATED COGSCREEN SUB-TESTS
						Long-term memory	SDC
					PERCEPTION	Visual processing	VSC, MTS, BDS, DAT, SAT, DTT, PF
					OTHER COGNITIVE FUNCTIONS	Deductive reasoning	SAT, MAT
					PSYCHOMOTOR COORDINATION	*Motor coordination	PF
						* Visual motor tracking	DTT

*Sustained attention and Psychomotor coordination are required when the pilot is actually flying.

Appendix J: Participant Informed Consent

The purpose of this informed consent is to ensure that you understand the purpose of this study and the nature of your involvement. The informed consent has to provide sufficient information such that you have the opportunity to determine whether or not you wish to participate in this study.

Study Title: Assessing CogScreen – AE as a Potential Pilot Selection Test.

Study Personnel: Elisa Cass Tel. (), EMAIL:

Dr. Avi Parush, Tel. 520.2600 (ext. 6026), EMAIL: avi_parush@carleton.ca

Lieutenant-Colonel Damian O’Keefe, Tel. EMAIL:

Should you have any ethical concerns about this study, please contact Dr. Monique Senechal, Chair, Carleton University Ethics Committee for Psychological Research, 613-520-2600 (ext. 1155) or Dr. Janet Mantler, Chair, Department of Psychology, Carleton University, 613-520-2600 (ext. 4173).

Purpose and Task Requirements: The purpose of this study is to assess the appropriateness of a potential Rotary Wing selection test namely the CogScreen – Aerospace (AE). To do so, we must understand the cognitive demands that are placed upon Rotary Wing (RW) pilots during a complex operational task namely, a deck landing, as a means of improving pilot selection tests. In doing so, you will be asked to complete the CogScreen – AE test battery which will take no longer than one hour; in addition to three deck landing simulations which will take approximately 10 – 15 minutes each. During each deck landing scenario, you will be asked to respond to task-related questions while the simulator is paused and the screen is blanked. This will occur several times during each scenario. Your participation will be required for one half day only. You will be afforded a long break after the CogScreen – AE and shorter breaks between simulator sessions as needed.

Potential Risk and Discomfort: This study is non-invasive but poses minimal risk of simulator sickness to participants. If you feel sick, anxious or uncomfortable, please bring your concerns to the researcher’s attention.

In accordance with 1 Canadian Air Division Headquarters Orders Volume 2-2 007 page 3/17 paragraph 9,

“Any aircrew who has conducted operations in the virtual environment of the HelMET shall be restricted from all flying duties for a period of 12 hours following the session”. However, this is not expected to limit your availability for further simulation or flight operations the following day.

Anonymity/Confidentiality: The data collected in this experiment are confidential. All data collected are encoded to afford you anonymity. The coded data will only be available to the researchers involved in this study. Your name will not be listed on the data itself.

Right to Withdraw: Your participation in this study is entirely voluntary. At any point during the study, you have the right to skip any questions or to withdraw without penalty.

I have read the above description of *Assessing CogScreen – AE as a Potential Pilot Selection Test* study and understand the requirements for participation. My signature indicates that I agree to participate in the study, and this in no way constitutes a waiver of my rights.

Full Name (please print): _____

Participant Signature: _____

Date: _____

Researcher Signature: _____

Date: _____

Appendix K: Pre-Brief A – Inexperienced Pilots

Participant Pre-Brief A

Thank you for participating in the “*Assessing CogScreen – AE as a Potential Pilot Selection Test*” study. Your involvement will help to improve the pilot selection model for Rotary Wing pilots. Participation consists of approximately 3.5 hours.

You will now be given a half-hour to study two related lesson plans that pertain to the HelMET simulator in order to familiarize yourself with two deck landing types – free deck and haul down landings. Following, you will sit in the HelMET simulator to observe a simulated free deck landing for familiarization purposes. Treat HelMET as if it were an actual CH - 124 Sea King throughout the familiarization session and all subsequent landing sequences. Assume that there is a virtual pilot, or co-pilot, (as the case may be) who will serve in the alternate role. Manipulate the stick and the collective (although they are non-responsive) and converse aloud as you normally would in your assigned position. This will help you to stay actively engaged throughout the simulations rather than as a passive observer.

During the familiarization session, you will experience what it is like when the simulator pauses and when the head mounted display blanks out. These pauses are intended and will occur several times during the familiarization session and throughout the three scenarios that follow. During the three trial scenarios, you will be asked a technical question during each pause that pertains to the given scenario and your role. You are to respond as quickly and accurately as possible. Additionally, you will be asked for a confidence rating from 1 - 5; 1 being not at all confident in your response, to 5 being confident with certainty. Your performance will be measured by the researcher and used for research purposes only. Your scores will not be shared with any superiors, subordinates or peers, nor will you be given your scores on the tests because the scores by themselves would be misleading. We will, however, conduct a study de-brief at the end of the simulator session to discuss your overall impressions. Do you have any questions?

Appendix L: Pre-Brief B – Experienced Pilots

Participant Pre-Brief B

Thank you for participating in the “*Assessing CogScreen – AE as a Potential Pilot Selection Test*” study. Your involvement will help to improve the pilot selection model for Rotary Wing pilots. Participation consists of approximately 3 hours.

You will now sit in the HelMET simulator to observe a simulated free deck landing for familiarization purposes. Treat HelMET as if it were an actual CH -124 Sea King throughout the familiarization session and all subsequent landing sequences. Assume that there is a virtual pilot, or co-pilot, (as the case may be) who will serve in the alternate role. Manipulate the stick and the collective (although they are non-responsive) and converse aloud as you normally would in your assigned position. This will help you to stay actively engaged throughout the simulations rather than as a passive observer.

During the familiarization session, you will experience what it is like when the simulator pauses and when the head mounted display blanks out. These pauses are intended and will occur several times during the familiarization session and throughout the three scenarios that follow. During the three trial scenarios, you will be asked a technical question during each pause that pertains to the given scenario and your role. You are to respond as quickly and accurately as possible. Additionally, you will be asked for a confidence rating from 1 - 5; 1 being not at all confident in your response, to 5 being confident with certainty. Your performance will be measured by the researcher and used for research purposes only. Your scores will not be shared with any superiors, subordinates or peers, nor will you be given your scores on the tests because the scores by themselves would be misleading. We will, however, conduct a study de-brief at the end of the simulator session to discuss your overall impressions. Do you have any questions or concerns?

Appendix M: CogScreen – AE Set-Up Guide and Verbatim Instructions

CogScreen – AE Set-Up Guide

Once a week recalibrate the two CogScreen – AE computers.

Calibration

- Double-click on the ELO shortcut on desktop.
- Select MODE tab.
- Change radial button to Enhanced
- Select the General Tab
- Click Align.
- Hold the stylus perpendicular (90 degree angle) to the surface of the screen.
- Carefully select the center of each large bull's eye presented.
- Then, select the center of each small bull's eye presented in the four corners of the screen.
- Next, draw a wavy squiggle or circle on the white screen. If the icon on the screen follows the stylus's movements, click the green check box. If the arrow icon does not follow the stylus' movements, click the red cancel box.
- Click OK.
- Repeat these steps at any time to ensure proper touch screen calibration.

Starting the CogScreen – AE testing program

- Double click on the CogScreen Icon
- Enter "PilotSA" [Enter] (if needed)
- Enter Examiner Username and Examiner Password (case sensitive)
- Click OK
- The Select Examinee screen appears.
- Enter the examinee's code – (case sensitive). (The name cannot be more than 10 characters).
- Enter DOB and you'll get an "examinee not found message". This is good.

With the candidate

- Enter subject's code under name e.g. A B Initio 1/DOB/number of logged hours/test considerations.
- Place the keyboard out of the way until needed for the Dual Task Test.

[The examiner should be in the background to monitor the tests to see if the participant is having difficulty reading the text, using the stylus or following the instructions and to respond to any "contact the administrator" screens. The examiner will also need to demonstrate the Dual Task Tracking task during the practice stage. The examiner should feel free to provide explanations and demonstrations as needed when instructions are being presented but not during sub-tests].

Discontinuing a test

If the participant is incapable of continuing with the test battery, simultaneously press "Alt + F1". This cannot be done when a test is actually running. However during the test instructions and upon completion of practice items, it is possible to halt testing.

Generally, this feature is active when there is a NEXT box appearing in the lower right hand corner of the screen.

Press Alt + F1 and choose an option

1. Skip the subtest for now.
2. Restart the subtest from the beginning now
3. To remove the subtest from this session's test battery, press Esc to end this session.

Finishing the test

When the TESTING IS COMPLETED screen appears, the subject has completed the entire test battery. The screen will not respond to button presses.

If the examinee did not complete some of the sub-tests, the screen will indicate that testing was not completed and will show the number of incomplete sub-tests.

The examiner types in the letters “m a i n” and then press [Enter].

If the system doesn’t respond, press the [Enter] key again, then type the letters “m a i n” and then press [Enter].

The screen will go blank and then the Examiner’s Observations screen will appear.

Examiner’s Observations (done after the participant leaves)

- 1) Check boxes that apply for problematic behaviours observed during testing.
- 2) If computer or software failures occurred (e.g. Power outage) indicate in the appropriate field.
- 3) Describe the examinee’s mood during the testing.
- 4) Provide other pertinent observations.

Click NEXT

Exiting

If the entire test battery was not completed two options will appear:

- 1) Examinee will return to complete sub-tests later.
- 2) Examinee requires no further testing.

If the first option is chosen, the CogScreen - AE results will not be available for the Aeromedical report until the subject completes the remaining sub-tests.

Accessing the CogScreen – AE Data

- 1) Log on using the Professional name “Cass” and password (k20)
- 2) Examinees are listed in the box on the left in alphabetical order.

3) To view demographics, double click on the Examinee's name and then select the session completed by the subject. Incomplete sessions appear with a clear page icon/completed sessions appear with a filled page icon. You will only be able to generate an Aeromedical report if the filled page icon is present.

4) Demographics may be edited directly on the Demographics screen on the right side.

5) To generate the Aeromedical Report click on the Reports tab and select the Aeromedical Report option.

Codes:

“Alt –F1” to escape out of subtest (issues)

“F1” to skip the subtest now

“F2” To restart the sub-test from the beginning now

“F3” To remove the subtest from this session's test battery

“Esc” To end this session

CogScreen - AE
Verbatim Instructions

There are 13 sub-tests in this battery. Each sub-test will begin with a title screen and instructions, which I would like you to read very carefully. If there are further instructions on the following screen, the screen will feature a “NEXT” button. You must press the “NEXT” button to go on to the remaining instructions.

After reading the sub-test instructions, you will be given practice items to ensure you understand what is expected before proceeding with the actual test items. After you have completed the practice items, you will have an opportunity to review them again, or, proceed with the actual sub-test. You may review the practice items more than once. Also, if you did not do well on a given practice session, the computer will have you review the practice items again. Do not be concerned over this since it is normal to find some tests relatively easy while others may be more difficult.

[If the participant wants to practice a third time, the screen will say – See your Administrator”. The examiner will hit Alt F1 (1) to repeat the instructions a third time and then watch the participant do the third practice session. If the participant gets “see administrator again, hit Alt F1 to override and hit “Start test” (2).] If the respondent is still not capable of performing a sub-test, then it can be skipped (3).

Before we begin, you must become familiar with the use of the stylus. The stylus is the instrument you will use on the touch screen monitor to record your answers. Hold the stylus in the same manner as you would normally hold a pen or pencil. The tip of the stylus is to tap the screen with the tip perpendicular to the face of the monitor and

not at an angle. Remember to keep your arm resting on the table or gel pad with the stylus close to the screen. Your score depends on speed and accuracy.

On the Pathfinder test, you will be instructed to not only tap the boxes, but to try to tap the number or letter that is inside the box. For the Shifting Attention Test Discovery Condition, there will be no practice items. Make sure you understand the instructions before proceeding to the test. When you get to the Dual Task Tracking test, you will be prompted to call me over to show you how to correctly place the keyboard and what is required for this test. Do you have any questions?

Keyboard Demonstration for:

Dual Task Tracking Alone sub-test

Place keyboard to the left of participant if right-handed or, place keyboard to right of participant if left-handed.

Slowly tap the left and right arrow keys and verbalize “Left”, “Right”, “Left”, and “Right” as you press the arrow keys. This will be easier to control if you make fewer key presses. You cannot hold down the keys, otherwise you will hit the boundaries and it will count against you. Repeat the instructions to give yourself adequate tracking practice.

Appendix N: Randomization of Order

Inexperienced pilots research ID #	Scenario order	Experienced pilots research ID #	Scenario order
A5	BCD	B1	DBC
A6	CDB	B2	BCD
A7	DBC	B2	CDB
A8	BCD	B4	DBC
A9	CDB	B5	BCD
A10	DBC	B6	CDB
A11	BCD	B7	DBC
A12	CDB	B8	BCD
A13	DBC	B9	CDB
A14	BCD	B10	DBC
A15	CDB	B11	BCD
A16	DBC	B12	CDB
A17	BCD	B13	DBC
		B14	BCD
N = 13 Inexperienced Pilots		N = 14 Experienced Pilots	

Appendix O: HelMET Simulator Scenario Set-Up Instructions

HelMET (Familiarization)

As the flying pilot in a real CH - 124 Sea King setting, you manipulate the flight controls. However, the Helicopter Maritime Environmental Trainer (HelMET) works on auto-pilot and in essence flies itself. For research purposes, it is very important to be actively engaged during all sessions. For this reason, while using HelMET you will participate in the scenario as if hands/feet were operating the flight controls. In other words, perform as you normally would in a live deck-landing scenario in regards to instruments, communications and actions.

This initial scenario will serve as a familiarization of HelMET and to get you ready for the three trials that follow. During the trials, you can expect the simulator to freeze several times throughout the deck landing scenario and your head mounted display to go blank. These pauses are intended. For this scenario, you will simply experience what will happen at each stoppage in preparation for the three scenarios that follow.

For this scenario:

- You are the flying pilot situated in the Right-Hand seat.
- You are virtually “backed up” by a senior pilot in the Left-Hand seat.
- All communications (ship’s internal and helo internal communications and radios) are complete and correct.
- Communications between persons aboard ship and the helo have been tested and function correctly.
- Call signs for this scenario are: Warship and HelMET 0-1.

Do you have any questions before we begin?

HelMET Scenario B

With this scenario and all subsequent sessions, the motion-base will be engaged and the simulator will be frozen several times throughout. You will be asked a technical question during each stoppage/blanking of the screen at which time you will respond as quickly and accurately as you can. Your responses will be scored. Upon giving your response, you will also be asked to give a confidence rating for your answer (confidence rating 1 –5; 1 - being no confidence in your answer to 5 - being confident with certainty). Once you have given your answer and your confidence rating, the scenario will proceed. Continue to perform as you normally would in a real flight situation. Therefore, manoeuvre the stick and lower the collective when descending and push it down on landing and communicate aloud as you normally would.

In this scenario:

- You are conducting a pilot-monitored approach (PMA) from the Right-hand seat, observing the flight characteristics/performance of the helo.
- The 'other' pilot will virtually fly the approach from the Left-hand seat.
- At ½ NM, as the non-flying pilot, if visual, call "I have the con" and proceed by conning the flying pilot to a Delta Hover Astern position off the ship that provides better visual references. Once satisfied with visual references call "coming on the controls" followed by "I have control" and take the landing.
- The aircraft weight is 16,000 lbs.
- All communications (ship's internal and helo internal communications and radios) are complete and correct. Specifically all communications between the SAC and helo (on tactical and Lima-lima) have been tested and are functioning correctly.
- Call signs for this scenario are: Warship and HelMET 0-1.
- Do you have any questions before we begin?

HelMET Scenario C

With this scenario and all subsequent sessions, the motion-base will be engaged and the simulator will be frozen several times throughout. You will be asked a technical question during each stoppage/blanking of the screen at which time you will respond as quickly and accurately as you can. Your responses will be scored. Upon giving your response, you will also be asked to give a confidence rating for your answer (confidence rating 1 – 5; 1 - being no confidence in your answer to 5 - being confident with certainty). Once you have given your answer and your confidence rating, the scenario will proceed. Continue to perform as you normally would in a real flight situation. Therefore, manoeuvre the stick and lower the collective when descending and push it down on landing and communicate aloud as you normally would.

In this scenario:

- You are conducting a pilot-monitored approach (PMA) from the Left-hand seat, observing the flight characteristics/performance of the helo.
- The 'other' pilot will virtually fly the approach from the Right-hand seat.
- At ½ NM, as the non-flying pilot, if visual call "I have the con" and proceed by conning the flying pilot to a Delta Hover Astern position off the ship that provides better visual references. Once satisfied with visual references call "coming on the controls" followed by "I have control" and take the landing.
- The aircraft weighs 16,000 lbs.
- All communications (ship's internal and helo internal communications and radios) are complete and correct. Specifically, all communications between the SAC and helo (on tactical and Lima-lima) have been tested and are functioning correctly.
- Call signs for this scenario are: Warship and HelMET 0-1.
- Do you have any questions before we begin?

HelMET Scenario D

With this scenario and all subsequent sessions, the motion-base will be engaged and the simulator will be frozen several times throughout. You will be asked a technical question during each stoppage/blanking of the screen at which time you will respond as quickly and accurately as you can. Your responses will be scored. Upon giving your response, you will also be asked to give a confidence rating for your answer (confidence rating 1 –5; 1 - being no confidence in your answer to 5 - being confident with certainty). Once you have given your answer and your confidence rating, the scenario will proceed. Continue to perform as you normally would in a real flight situation. Therefore, manoeuvre the stick and lower the collective when descending and push it down on landing and communicate aloud as you normally would.

In this scenario:

- You are conducting a pilot-monitored approach (PMA) from the Right-hand seat, observing the flight characteristics/performance of the helo.
- The 'other' pilot will virtually fly the approach from the Left-hand seat.
- At ½ NM, as the non-flying pilot, if visual call "I have the con" and proceed by conning the flying pilot to a Delta Hover Astern position off the ship that provides better visual references. Once satisfied with visual references call "coming on the controls" followed by "I have control" and take the landing.
- The aircraft weight is 16,000 lbs.
- All communications (ship's internal and helo internal communications and radios) are complete and correct. Specifically all communications between the SAC and helo (on tactical and Lima-lima) have been tested and are functioning correctly.
- Call signs for this scenario are: Warship and HelMET 0-1.
- Do you have any questions before we begin?

Appendix P: Participant Debrief

Participant Debrief

Thank you for participating in this important Rotary Wing selection study. The necessary data has been collected from you as a participant, ending your involvement. As such, I will take this opportunity to expand upon the purpose and rationale for this experiment. I would ask that you do not share the information below with other pilots, participants or Wing personnel as data collection will be ongoing for some time.

As indicated by the title on your informed consent, the purpose of this study is to assess the CogScreen – (Aerospace Edition) as a potential pilot selection test. More specifically, I am hopeful that this test might predict situation awareness. Up until now, situation awareness has been introduced through pilot training and in some cases, improved with time and experience. However, it has not been assessed for selection. Thus, the research question is: “Can situation awareness be predicted? Investigating relationships between the CogScreen – AE and situation awareness”.

The hypotheses for this study are twofold: CogScreen – AE will demonstrate a positive relationship with the situation awareness performance scores and inexperienced Sea King pilots who perform well on the situation awareness task will also perform well on the CogScreen – AE test. This would demonstrate the viability of CogScreen – AE as a predictive situation awareness measure for Rotary Wing pilot selection and serve as a proof of principle to the Canadian Forces for further consideration. I have read and understand the purpose behind this study and will not divulge the above information to others, particularly fellow pilots as they may be involved in this study.

Participant's Name	Signature	Date
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Principal Investigator's Name	Signature	Date
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Should you wish further information on this study, you may contact any of the following personnel:

Research personnel:

Principal Investigator: Major Elisa Cass Tel.

EMAIL:

Carleton University Faculty Sponsor: Dr. Avi Parush, Tel. 520.2600, ext. 6026

EMAIL: avi_parush@carleton.ca

DMPORA 2 Office of Primary Interest: LCol Damian O'Keefe, Tel.

EMAIL:

Ethical concerns:

Chair of Carleton University Ethics Committee for Psychological Research:

Dr. Monique Sénéchal Tel. 613-520-2600, ext. 1155

Any other concerns:

Chair of the Department of Psychology, Carleton University

Dr. Janet Mantler, Tel. 613-520-2600, ext. 4173

Appendix Q: Descriptive Statistics and Significant Results

Situation Awareness Accuracy Scores

Table Q1

Between-Subjects Factors for Situation Awareness Accuracy Scores

	Between-subjects factors				
	Experience group		Scenario order		
	Inexperienced Pilots	Experienced Pilots	BCD	CDB	DBC
Sample size	13	14	9	9	9

Table Q2

Within-Subjects Factors for Situation Awareness Accuracy Scores

Scenario	Situation awareness levels	Dependent variables
Scenario B	1	Scenario B Level 1 accuracy
	2	Scenario B Level 2 accuracy
	3	Scenario B Level 3 accuracy
Scenario C	1	Scenario C Level 1 accuracy
	2	Scenario C Level 2 accuracy
	3	Scenario C Level 3 accuracy
Scenario D	1	Scenario D Level 1 accuracy
	2	Scenario D Level 2 accuracy
	3	Scenario D Level 3 accuracy

Scenario Order and Experience Factors

Table Q3

*Analysis of Variance for Situation Awareness Accuracy Scores When
Experience and Scenario Order are Factors*

Source	df	F	η	ρ
Between subjects				
Experience	1	10.24	.33	.00**
Order	2	.66	.06	.53
Experience X Order	2	.13	.01	.88
S within-group error	21	(.32)		
Within subjects				
Scenario	2	3.86	.16	.03*
Scenario X Experience	2	.59	.03	.56
Scenario X Order	4	6.73	.39	.00**
Scenario X Experience X Order	4	2.55	.20	.05
Scenario X S within-group error	42	(.10)		
SA level	2	4.08	.16	.02*
SA level X Experience	2	.44	.02	.65
SA level X Order	4	.38	.03	.83
SA level X Experience X Order	4	.30	.03	.87
SA level X S within-subjects error	42	(.16)		
Scenario X SA level	4	1.24	.06	.30
Scenario X SA level X Experience	4	1.26	.06	.29
Scenario X SA level X Order	8	.87	.08	.55
Scenario X SA level X Experience X Order	8	.50	.05	.86
Order				
Scenario X SA level	84	(.19)		
S within-subjects error				

Note. Values enclosed in parentheses represent mean square errors. S = subjects. * $p < .05$. ** $p < .01$.

Table Q4

Mauchley's Test of Sphericity for Situation Awareness Accuracy Scores When Experience and Order are Factors

Within-Subjects Effect	Mauchley's ω	df	ρ
Scenario	.97	2	.74
Situation awareness level	.96	2	.69
Scenario X Situation awareness level	.87	9	.98

Note. Sphericity assumed.

Table Q5

Estimated Marginal Means for Approaching Three-Way Interaction Between Scenario Order, Experience levels, and Scenario When Order is a Factor

<u>Inexperienced</u>						
Scenario	BCD	<u>Mean</u>		BCD	<u>SE</u>	
		CDB	DBC		CDB	DBC
B	.42	.33	.87	.12	.12	.10
C	.75	.67	.33	.12	.12	.10
D	.75	.67	.73	.13	.13	.11
<u>Experienced</u>						
Scenario	BCD	<u>Mean</u>		BCD	<u>SE</u>	
		CDB	DBC		CDB	DBC
B	.73	.73	.93	.10	.10	.12
C	.87	.87	.83	.10	.10	.12
D	.87	.80	1.00	.11	.11	.13

Table Q6

*Estimated Marginal Means for Two – Way Interaction Between
Scenario Order and Scenario when Order is a Factor*

Scenario	<u>Scenario Order</u>					
		<u>Mean</u>			<u>SE</u>	
	BCD	CDB	DBC	BCD	CDB	DBC
B	.58	.53	.89	.08	.08	.08
C	.81	.77	.58	.08	.08	.08
D	.82	.73	.87	.08	.08	.08

Table Q7

*Estimated Marginal Means for Main Effects-Experience, Scenario,
and Situation Awareness Level when Order is a Factor*

Source	Mean	SE
Experience		
Inexperienced	.61	.05
Experienced	.85	.05
Scenarios		
B	.67	.05
C	.72	.05
D	.80	.05
Situation awareness level		
1	.71	.06
2	.83	.04
3	.65	.06

Experience Factors

Table Q8

*Analysis of Variance for Situation Awareness Accuracy Scores when**Experience is the Only Factor*

<i>Source</i>	<i>df</i>	<i>F</i>	<i>η</i>	<i>ρ</i>
Between subjects				
<i>Experience</i>	1	10.77	.30	.00**
<i>S within-group error</i>	25	(.29)		
Within subjects				
Scenario	2	2.12	.08	.13
Scenario X Experience	2	.55	.02	.58
Scenario X <i>S</i> within-group error	50	(.16)		
SA level	2	4.36	.15	.02*
SA level X Experience	2	.55	.02	.58
SA level X <i>S</i> within-subjects error	50	(.15)		
Scenario X SA level	4	1.36	.05	.26
Scenario X SA level X Experience	4	1.56	.06	.19
Scenario X SA level <i>S</i> within-subjects error	100	.18		

Note Values enclosed in parentheses represent mean square errors S = subjects * $p < .05$ ** $p < .01$

Table Q9

Mauchley's Test of Sphericity for Situation Awareness Accuracy Scores when Experience is the Only Factor

Within-Subjects Effect	Mauchley's ω	<i>df</i>	ρ
Scenario	.86	2	.16
Situation awareness level	.95	2	.54
Scenario X Situation awareness level	.87	9	.95

Note. Sphericity assumed.

Table Q10

Estimated Marginal Means for Main Effects- Experience Levels, and Situation Awareness Levels

	Mean	SE
Experience level		
Inexperienced pilots	.62	.05
Experienced pilots	.84	.05
Situation awareness level		
1	.71	.05
2	.82	.04
3	.65	.06

Table Q11

Pairwise Comparisons – Situation Awareness Levels

Situation awareness level		Mean difference	SE	ρ
1	2	-.11	.05	.05
	3	.06	.07	.35
2	1	.11	.05	.05
	3	.18	.06	.01*
3	1	-.06	.07	.35
	2	-.18	.06	.01*

Note. $p < .05$

*Confidence Ratings**Scenario Order and Experience Factors*

Table Q12

*Between-Subjects Factors: Experience Levels and Scenario Order for Confidence**Ratings*

	Between-subjects factors				
	Experience group		Scenario order		
	Inexperienced Pilots	Experienced Pilots	BCD	CDB	DBC
Sample size	13	14	9	9	9

Table Q13

*Within-Subjects Factors: Scenario and Situation Awareness Levels for Confidence**Ratings*

Scenario	Situation awareness levels	Dependent variables
Scenario B	1	Scenario B Level 1 confidence
	2	Scenario B Level 2 confidence
	3	Scenario B Level 3 confidence
Scenario C	1	Scenario C Level 1 confidence
	2	Scenario C Level 2 confidence
	3	Scenario C Level 3 confidence
Scenario D	1	Scenario D Level 1 confidence
	2	Scenario D Level 2 confidence
	3	Scenario D Level 3 confidence

Table Q14

*Analysis of Variance for Confidence Ratings when
Experience and Scenario Order are Factors*

Source	<i>df</i>	<i>F</i>	η	ρ
Between subjects				
Experience	1	34.99	.63	.00**
Order	2	3.38	.24	.05
Experience X Order	2	.69	.06	.52
<i>S</i> within-group error	21	(2.6)		
Within subjects				
Scenario	2	2.50	.11	.09
Scenario X Experience	2	1.21	.06	.31
Scenario X Order	4	.95	.08	.44
Scenario X Experience X Order	4	3.81	.27	.01*
Scenario X <i>S</i> within-group error	42	(1.14)		
SA level	2	.22	.01	.80
SA level X Experience	2	1.49	.07	.24
SA level X Order	4	1.03	.09	.41
SA level X Experience X Order	4	1.91	.15	.13
SA level X <i>S</i> within-subjects error	42	(.91)		
Scenario X SA level	4	3.98	.16	.01*
Scenario X SA level X Experience	4	.92	.04	.46
Scenario X SA level X Order	8	1.11	.10	.37
Scenario X SA level X Experience X Order	8	1.92	.15	.07
Order				
Scenario X SA level	84	(1.19)		
<i>S</i> within-subjects error				

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects. * $p < .05$. ** $p < .01$.

Table Q15

*Mauchley's Test of Sphericity for Confidence Ratings when
Experience and Order are Factors*

Within-subjects Effect	<i>Mauchley's ω</i>	<i>df</i>	<i>p</i>
Scenario	.98	2	.82
Situation awareness level	.96	2	.66
Scenario X Situation awareness level	.84	9	.48

Note. Sphericity assumed.

Table Q16

*Estimated Marginal Means for Three-Way Interaction Between
Experience levels, Scenario Order and Scenario on Confidence Ratings*

Mean				SE		
Inexperienced						
Scenario	BCD	CDB	DBC	BCD	CDB	DBC
B	2.50	2.92	3.93	.34	.34	.31
C	3.42	2.58	3.13	.39	.39	.35
D	3.83	2.92	4.13	.38	.38	.34
Experienced						
Scenario	BCD	CDB	DBC	BCD	CDB	DBC
B	4.67	4.20	4.67	.31	.31	.34
C	3.73	4.60	4.92	.35	.35	.39
D	4.67	4.33	4.67	.34	.34	.38

Table Q17

*Estimated Marginal Means for Two- Way Interaction Between
Situation Awareness Levels and Scenario on Confidence Ratings*

Scenario	Scenario Order					
	Mean			SE		
	SA Level 1	SA Level 2	SA Level 3	SA Level 1	SA Level 2	SA Level 3
B	3.82	4.24	3.38	.22	.21	.23
C	3.69	3.39	4.12	.23	.29	.15
D	4.12	3.86	4.30	.19	.24	.19

Table Q18

*Estimated Marginal Means for Main Effect - Experience Levels
on Confidence Ratings*

<u>Experience Level</u>	<u>Mean</u>	<u>SE</u>
Inexperienced	3.26	.15
Experienced	4.49	.14

Table Q19

*Estimated Marginal Means for Approaching Main Effects**Scenario Order on Confidence Ratings*

<u>Scenario order</u>	<u>Mean</u>	<u>SE</u>
BCD	3.80	.18
CDB	3.59	.18
DBC	4.24	.18

Table Q20

Pairwise Comparisons for Scenario Order on Confidence Ratings

Scenario Order		Mean difference	SE	p
BCD	CDB	.21	.26	.42
	DBC	-.44	.26	.10
CDB	BCD	-.21	.26	.42
	DBC	-.65	.26	.02*
DBC	BCD	.44	.26	.10
	CDB	.65	.26	.02*

*Note. * $p < .05$*

*Confidence Ratings**Experience Factor*

Table Q21

Analysis of Variance for Confidence Ratings when Experience is the Only Factor

<i>Source</i>	<i>df</i>	<i>F</i>	<i>η</i>	<i>ρ</i>
Between subjects				
<i>Experience</i>	1	27.74	.54	.00*
<i>S within-group error</i>	25	(3.03)		
Within subjects				
Scenario	2	2.31	.08	.11
Scenario X Experience	2	.95	.04	.39
Scenario X <i>S</i> within-group error	50	(1.40)		
SA level	2	.38	.02	.68
SA level X Experience	2	1.58	.06	.22
SA level X <i>S</i> within-subjects error	50	(.98)		
Scenario X SA level	4	3.51	.12	.01*
Scenario X SA level X Experience	4	.75	.03	.56
Scenario X SA level <i>S</i> within-subjects error	100	(1.30)		

Note. Values enclosed in parentheses represent mean square errors. S = subjects. * $p < .05$. ** $p < .01$.

Table Q22

Mauchley's Test of Sphericity for Confidence Ratings when

Experience is the Only Factor

Within-subjects Effect	Mauchley's ω	df	p
Scenario	.91	2	.33
Situation awareness level	.90	2	.28
Scenario X Situation awareness level	.76	9	.69

Note. Sphericity assumed.

Table Q23

Estimated Marginal Means - Two –Way Interaction Between Situation Awareness Levels

and Scenario on Confidence Ratings with Experience Level as the Only Factor

Scenario Order						
Scenario	<u>Mean</u>			<u>SE</u>		
	SA Level 1	SA Level 2	SA Level 3	SA Level 1	SA Level 2	SA Level 3
B	3.83	4.24	3.45	.25	.19	.26
C	3.65	3.37	4.12	.27	.27	.18
D	4.14	3.87	4.31	.21	.24	.18

Table Q24

Estimated Marginal Means for Main Effect Experience Level

<u>Experience Level</u>	<u>Mean</u>	<u>SE</u>
Inexperienced pilots	3.23	.16
Experienced pilots	4.48	.16

*Regression**Mean Situation Awareness Accuracy Scores and Mean Confidence Ratings*

Table Q25

*Descriptive Statistics for Experience Levels' Mean Situation Awareness Accuracy Scores
and Mean Confidence Ratings*

<u>Experience Level</u>	<u>Situation awareness accuracy</u>		<u>Confidence ratings</u>		<u>N</u>
	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	
Inexperienced	.62	.23	3.28	.75	13
Experienced	.84	.11	4.48	.39	14

Table Q26

Regression statistics for Mean Accuracy Scores and Mean Confidence Scores

Experience level	<i>R</i>	<i>R</i> ²	Adjusted <i>R</i> ²	SE of the estimate	<i>B</i>	<i>SE B</i>	β
Inexperienced	.83	.68	.65	.44	2.69	.55	.83
Experienced	.33	.11	.03	.38	1.13	.94	.33

CogScreen – AE Statistical Data

CogScreen – AE Accuracy Scores for Experience Levels

Table Q27

Analysis of Variance – Experience levels' CogScreen Accuracy Performance

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Backward Digit Span	1	.01	.00	.92
error	25	(148.48)		
Math	1	.34	.01	.56
error	25	(148.48)		
Visual Sequence Comparison	1	16.53	.10	.11
error	25	(6.00)		
Difference in Sequence Comparison	1	3.00	.11	.10
error	25	(13.81)		
Symbol Digit Coding	1	.030	.01	.86
error	25	(.93)		
Symbol Digit Immediate Recall	1	3.02	.12	.10

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Matching to Sample	1	.03	.00	.87
error	25	(28.93)		
Manikin	1	1.36	.05	.25
error	25	(14.42)		
Divided Attention Sequence Comparison	1	.003	.00	.96
error	25	(10.46)		
Auditory Sequence Comparison	1	.02	.00	.89
error	25	(50.92)		
Pathfinder Letter	1	.28	.01	.60
error	25	(1.83)		
Pathfinder Combined	1	.02	.00	.91
error	25	(8.79)		
Symbol Digit Coding Delayed Recall	1	3.08	.11	.09
error	25	(3.86)		
Shifting Attention Arrow Direction	1	.93	.01	.35
error	25	(.01)		
Shifting Attention Arrow Color	1	.10	.00	.76
	25	(.03)		
Shifting Attention Instruction	1	2.24	.08	.15
Error	25	(6.56)		

Sub-test	<i>df</i>	<i>F</i>	η	ρ
error	25	(23.54)		
Dual Task Tracking Previous Number Alone	1	1.14	.04	.30
error	25	(7.96)		
Difference in Previous Number Alone	1	4.33	.15	.05
error	25	(31.72)		
Dual Task Tracking Previous Number Dual	1	2.80	.10	.11
error	25	(45.91)		

Note. Values enclosed in parentheses represent mean square errors. S = subjects. * $p < .05$. ** $p < .01$.

Table Q28

Analysis of Variance – Experience levels' CogScreen Thruput Performance

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Math	1	.51	.02	.48
error	25	(.25)		
Visual Sequence Comparison	1	.01	.00	.94
error	25	(33.20)		
Difference in Sequence Comparison	1	.46	.02	.51
error	25	(48.07)		
Symbol Digit Coding	1	7.98	.24	.01*
error	25	(61.74)		
Matching to Sample	1	2.22	.08	.15

error	25	(128.47)		
Sub-test	<i>df</i>	<i>F</i>	η	ρ
Manikin	1	.59	.02	.45
error	25	119.96		
Divided Attention Sequence Comparison	1	.73	.03	.40
error	25	(31.55)		
Auditory Sequence Comparison	1	.10	.00	.76
error	25	(470.74)		
Pathfinder Letter	1	1.04	.04	.32
error	25	(175.25)		
Pathfinder Combined	1	.65	.03	.43
error	25	(131.74)		
Shifting Attention Arrow Direction	1	1.76	.07	.20
error	25	(335.69)		
Shifting Attention Arrow Color	1	5.54	.18	.03*
error	25	(174.45)		
Shifting Attention Instruction	1	3.89	.13	.06
error	25	(362.97)		
Shifting Attention Discovery	1	4.39	.15	.05
error	25	(194.13)		
Dual Task Tracking Previous Number Alone	1	.05	.00	.83
error	25	(2888.52)		

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Difference in Previous Number Alone	1	66	03	42
error	25	(1802 40)		
Dual Task Tracking Previous Number Dual	1	21	01	65
error	25	(2606 68)		

Note Values enclosed in parentheses represent mean square errors S = subjects * $p < .05$ ** $p < .01$

Table Q29

Estimated Marginal Means for Experience Levels on CogScreen – AE Accuracy Scores

	<i>Difference in Previous Number Alone Task</i>		
Experience Level	<u>N</u>	<u>Mean</u>	<u>SE</u>
Inexperienced	13	- 49	1 56
Experienced	14	- 50	1 50

Table Q30

*Estimated Marginal Means for Experience Levels on**CogScreen – AE Thruput Scores*

		Symbol Digit Coding		Shifting Attention Arrow Color	
<u>Experience Level</u>	<u>N</u>	<u>Mean</u>	<u>SE</u>	<u>Mean</u>	<u>SE</u>
Inexperienced	13	47.29	2.18	112.33	3.66
Experienced	14	38.75	2.10	100.36	3.53

Thruput sub-tests approaching significance					
		Shifting Attention Discovery		Shifting Attention Instruction	
<u>Experience Level</u>	<u>N</u>	<u>Mean</u>	<u>SE</u>	<u>Mean</u>	<u>SE</u>
Inexperienced	13	60.02	3.86	101.37	5.29
Experienced	14	48.78	3.72	86.91	5.09

CogScreen – AE Accuracy Scores for Situation Awareness Performance Groups

Table Q31

*Analysis of Variance –Situation Awareness Performance Groups'**CogScreen - AE Accuracy Performance*

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Backward Digit Span	1	.00	.00	.94
error	25	(245.68)		
Math	1	.05	.00	.83
error	25	(150.22)		
Visual Sequence Comparison	1	2.78	.10	.10
error	25	(6.00)		
Difference in Sequence Comparison	1	.52	.02	.48
error	25	(15.15)		
Symbol Digit Coding	1	.56	.02	.46
error	25	(.92)		
Symbol Digit Immediate Recall	1	6.25	.20	.02*
error	25	(24.00)		
Matching to Sample	1	.26	.01	.62
error	25	(28.67)		
Manikin	1	.20	.08	.66
error	25	(15.08)		

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Divided Attention Sequence Comparison	1	1.17	.05	.29
error	25	(10.00)		
Auditory Sequence Comparison	1	.60	.02	.45
error	25	(49.78)		
Pathfinder Letter	1	.00	.00	1.00
error	25	(1.85)		
Pathfinder Combined	1	3.36	.12	.08
error	25	(7.76)		
Symbol Digit Coding Delayed Recall	1	6.38	.20	.02*
error	25	(3.45)		
Shifting Attention Arrow Direction	1	.49	.01	.49
error	25	(.01)		
Shifting Attention Arrow Color	1	.60	.02	.45
error	25	(.03)		
Shifting Attention Instruction	2	1.73	.07	.20
error	25	(6.68)		
Shifting Attention Discovery	1	1.81	.07	.19
error	25	(23.13)		

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Dual Task Tracking Previous Number Alone	1	.01	.00	.93
error	25	(8.33)		
Difference in Previous Number Alone	1	1.98	.07	.17
error	25	(34.48)		
Dual Task Tracking Previous Number Dual	1	.05	.00	.82
error	25	(50.94)		

Note. Values enclosed in parentheses represent mean square errors. S = subjects. * $p < .05$. ** $p < .01$.

Table Q32

Analysis of Variance –Situation Awareness Groups’ CogScreen Thruput Performance

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Math	1	.76	.03	.39
error	25	(.24)		
Visual Sequence Comparison	1	.97	.03	.33
error	25	(31.97)		
Difference in Sequence Comparison	1	2.45	.09	.13
error	25	(44.58)		
Symbol Digit Coding	1	3.57	.13	.07
error	25	(71.24)		

Sub-test	<i>df</i>	<i>F</i>	η	ρ
Matching to Sample	1	.05	.00	.83
error	25	(139.60)		
Manikin	1	.27	.01	.60
error	25	(121.48)		
Divided Attention Sequence Comparison	1	.63	.03	.43
error	25	(31.67)		
Auditory Sequence Comparison	1	1.19	.05	.29
error	25	(451.19)		
Pathfinder Letter	1	.13	.00	.73
error	25	181.64		
Pathfinder Combined	1	.00	.00	1.00
error	25	(135.16)		
Shifting Attention Arrow Direction	1	.33	.01	.57
error	25	(354.72)		
Shifting Attention Arrow Color	1	2.58	.09	.12
error	25	(193.18)		
Shifting Attention Instruction	1	1.02	.04	.32
error	25	(402.86)		
Shifting Attention Discovery	1	1.18	.05	.29
error	25	(217.96)		
Dual Task Tracking Previous Number Alone	1	.30	.01	.59

Sub-test	<i>df</i>	<i>F</i>	η	ρ
error	25	(2858.94)		
Difference in Previous Number Alone	1	.47	.02	.50
error	25	(1816.28)		
Dual Task Tracking Previous Number Dual	1	1.38	.05	.25
error	25	(2490.61)		

Note. Values enclosed in parentheses represent mean square errors. S = subjects. * $p < .05$. ** $p < .01$.

Table 33

Estimated Marginal Means for Situation Awareness Performance Groups on CogScreen

– AE Accuracy Scores

SA Performance Group	Symbol Digit Coding Immediate Recall			Symbol Digit Coding Delayed Recall	
	<u>N</u>	<u>Mean</u>	<u>SE</u>	<u>Mean</u>	<u>SE</u>
Low SA	13	95.00	1.63	98.08	.62
High SA	14	100.00	1.16	100.00	.44