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Optimizing Performance of Trainees for UAS Manpower, Interface and Selection (OPTUMIS): A Human Systems Integration (HSI) Approach

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Unmanned Aerial System (UAS) operations research by Williams (2004) found that platforms which employ winged aviators (e.g., Predator) have shown higher mishaps than those that select operators that are nonpilots (e.g., Shadow). One explanation may be negative training transfer from manned to unmanned platforms as operators are separated from the aircraft, thus depriving them of a range of sensory cues (McCarley & Wickens, 2007). Another explanation for higher Predator mishaps may be associated with poor Ground Control Station (GCS) design. These varying explanations for differences in mishap rates across platforms indicate the need to address a number of Human System Integration (HSI) issues including manpower/personnel, training, and design issues. Thus, this presentation discusses an effort investigating which UAS Knowledge, Skills, and Abilities, (KSAs) support the identification and training of candidates best suited to operate UASs. In addition, GCS design considerations directly linked to task workload and KSAs are discussed.

Authors' Note. The views expressed herein are those of the authors and do not necessarily reflect the official position of the organizations with which they are affiliated.

Human Systems Integration (HSI) is the multi-disciplinary marriage of systems engineering and behavioral science (Bost & Miller, 2003). HSI seeks to address issues associated with how the human interacts with other system elements (e.g., hardware/software) to ensure effective performance and safety. Within the DoD HSI consists of a number of disciplines including manpower/personnel, training, safety and health, habitability, survivability, and Human Factors (Bost & Miller, 2003). Manpower/Personnel addresses all aspects of defining requirements for personnel including selecting and retaining those individuals. Training seeks to equip personnel with the necessary KSAs for successful mission completion. Safety and health, habitability, and survivability seek to ensure that systems are designed to minimize personnel risk of injury and error, ensure that all aspects of the working spaces are designed with personnel in mind, and provide personnel with all requisite personal protection needed. Lastly, the Human Factors (HF) component of HSI seeks to ensure that all aspects of the system are designed with the full consideration of the inherent capabilities and limitations of personnel.

Research on UAS mishaps has begun to uncover fundamental HSI problems associated with selection, training, and design for UAS operations. Specifically, Williams (2004) found that UAS platforms utilizing winged aviators as operators (i.e., Predator) have significantly more HF related accidents than those operated by enlisted personnel (i.e., Shadow). Investigation of Predator accidents indicates issues concerning instrumentation, sensory feedback systems, and channelized attention. Conversely, Shadow HF accidents were found to be related to procedural guidance and publications, training issues, overconfidence and crew resource management (Thompson, Tvaryanas, & Constable, 2005). Although this comparison is of UASs from different groups, with Predators (Group IV) flying higher and faster than Shadows (Group III), this difference is unlikely to change the underlying HF issues associated with flying beyond visual range. One explanation for these findings may be negative training transfer from manned to unmanned platforms as operators are separated from the aircraft, thus depriving them of a range of sensory cues (McCarley & Wickens, 2007). This separation of aircraft and pilot puts winged aviators in a situation in which they are unable to employ the psychomotor skills that have been trained into automaticity (Grier et al., 2003), suggesting that winged aviators may not necessarily have the right competencies (i.e., KSAs) to operate a UAS. Additionally, Pagan et al. (2014) and Triplett (2008) found that there are core manned aviator KSAs that go unused when operating UASs (e.g., cognitive/spatial, physical/perceptual, and personality based competencies).

While researchers have begun to address *who* should operate UASs (e.g., McKinley, McIntire, & Funke, 2009; Pagan et al., 2014; Triplett, 2008), selection is only one component to addressing UAS mishaps from the HSI perspective. Another critical aspect is *system design* as multiple studies have cited confusion with interface and automation modes and difficulty with system management as primary causes for Predator HF related mishaps (Nullmeyer, Montijo, Herz, & Leonik, 2007; Thompson et al., 2005; Tvaryanas & Thompson, 2008).

These varying explanations for varying mishap rates across platforms, coupled with the fact that accident rates for Global Hawk, Predator, and Reaper are still three times higher than any other category of aircraft within the U.S. Air Force (Bloomberg, 2012) suggest further research is warranted. Specifically, research is necessary to identify the right individuals with the capabilities to acquire UAS specific skills and ensure they are trained to the appropriate KSAs, as well as to derive GCS design guidance that is optimized in a manner that improves overall safety and performance. The Optimizing Performance of Trainees for UAS Manpower, Interface and Selection (OPTUMIS) effort was developed to address these HSI concerns. OPTUMIS consists of three phases: 1) KSA Comparison (manned vs. unmanned), 2) Air Vehicle Operator (AVO) KSA Classification (select, train, design), and 3) Performance Differences. This paper describes preliminary results from the second phase of this research effort. Specifically, this paper will discusses our attempt to identify those KSAs that should be used for selection and those that should be used for training U.S. Navy UAS AVOs, as well as discusses UAS GCS design considerations that are directly linked to UAS operator task workload.

Method

Measures

Job Task Analyses (JTAs). The Analysis of Cross-Platform Naval Unmanned Aircraft System Task and Competency Requirements (Mangos, Vincenzi, Shrader, Williams, & Arnold, 2012) was used to identify UAS AVOs tasks and requisite KSAs. This JTA focused on all major UAS systems actively used by the U.S. Navy and Marine Corps. This JTA identified 256 general and system-specific operator (i.e., crew member, by position) tasks and 67 requisite KSAs across platforms. The Mangos et al., 2012 JTA also provided task difficulty, importance, and frequency SME ratings as well as KSA SME importance ratings. Additionally, a qualitative analysis of existing UAS JTAs was conducted to ensure a comprehensive list of KSAs was included for further analyses.[1] This analysis identified another 42 requisite KSAs bringing the total to 109 UAS cross-platform relevant competencies.

Existing Measures for Selection, Training, and Design Classification. An analysis of existing methods for providing selection, training, and system design guidance that is linked directly to requisite tasks and KSAOs was conducted. This analysis involved three steps: 1) identifying overlap among existing methods, 2) identifying unique methods, and 3) expanding/developing a model for design guidance. Results from this analysis deemed it necessary to expand the Brannick and Levine (2002) model for training and selection guidance to include design guidance. This updated model was used to develop techniques and collect required KSA and task information (e.g., ranking, categorizing, and elaborating) from UAS SMEs in order to obtain selection, training, and GCS design recommendations.

AVO KSA Classification Survey. The AVO KSA Classification Survey was developed utilizing the Brannick and Levine (2002) model for KSA Selection and Training classification. Each KSA was presented with a definition and SMEs were asked to provide consensus ratings for each KSA on four scales:

- *Necessary*: Is the attribute necessary for newly hired employees to possess upon entering the job? This is a dichotomous, yes/no response.
- *Practical*: Is the attribute practical to expect of incoming employees in the current labor market? Also a dichotomous, yes/no response.
- *Trouble Likely*: To what extent is trouble on the job likely if this attribute is ignored in selection (compared with the other attributes)? This is a 5-point scale ranging from “very little or none” (1) to “an extremely great extent” (5).
- *Superior from Average*. To what extent do different levels of the KSA distinguish the superior from the average operator (compared to the other KSAs)? The Superior from Average scale was rated on the same 5-point scale as the Trouble Likely scale.

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[1]Due to space limitations a complete listing of UAS JTAs utilized for this effort was not provided. For a complete listing of utilized UAS JTAs please contact the study authors.

Participants

Seven U.S. Navy UAS operators were asked to provide consensus ratings for the AVO KSA Classification Survey. Operators' backgrounds consisted of AVOs (2), Mission Commanders (3), and a Sensor Operator (1). Their experience ranged from 10 months to 3.5 years in Groups III -V (e.g. Shadow, Fire Scout, Broad Area Maritime Surveillance Demonstrator [BAMS-D]).

Results

A multi-pronged approached was used to classify KSAs into selection, training, or design categories. First, data from the KSA Classification Survey was used to classify selection and training categories.

Selection. KSAs were classified as required for selection based on the Brannick and Levine (2002) criteria: KSAs rated as "Necessary", "Practical", and 1.5 or higher on the "Trouble Likely" scale. Subsequently, selection KSAs were ranked based on a weighted score derived from multiplying scores on the "Trouble Likely" scale by scores on the "Superior from Average" scale (Brannick & Levine, 2002). Next, the "select to" KSAs were cross referenced with the KSA importance ratings from the Mangos et al., 2012 JTA to ensure all selection KSAs were rated as greater than moderately important on the five point importance scale used (i.e., 3.5 or greater). Finally, KSAs that were considered to be minimum qualifications for job performance we removed (e.g., general health, dynamic flexibility). The resulting KSAs are presented in Table 1. The KSAs presented in Table 1 are broken into four tiers. KSAs within a tier are grouped by importance ranking for selection (i.e., Tier 1 KSAs are most valuable for selection of UAS operators and Tier 4 are least valuable).

Table 1.
UAS Operator "Select To" KSAs

Tier 1		Tier 2	Tier 3	Tier 4
Dependable	Auditory Attention /Localization	Rule Abiding	Interpersonal Skills	Oral Expression
Self-Discipline	Finger Dexterity	Learning Ability	Cooperation	Oral Comprehension
Accountability	Wrist-Finger Speed	Numerical Reasoning	Listening Skills	
Mathematical Ability	Multi-limb Coordination	Work Motivation		
Control Precision	Vigilance	Perseverance		
Manual Dexterity	Resilience	Straightforward-ness		
Hand-Eye Coordination	Moral Interest	Cohesiveness		
Reaction Time	Attention to Detail	Extraversion		
Information Management Skills				

Training. Next, KSAs required for training were classified and ranked using the Brannick and Levine, 2002 methodology: KSAs were classified for training if they were rated as *not* "Necessary" and given a greater than 1.5 rating on the "Superior from Average" scale; training KSAs were then ranked based on their "Superior from Average" score. Then these KSAs were cross-referenced with the Mangos et al., 2012 KSA importance ratings. The resulting "train to" KSAs are presented in Table 2.

Table 2.
UAS Operator "Train To" KSAs

Tier 1			Tier 2	Tier 3
Deliberation	Planning	Threat Categories and Indicators	Mechanical Comprehension	Confidence
Adaptability	Safety Consciousness	Reconnaissance Procedures	Perceptual Speed and Accuracy	Long-Term Memory
Stress Tolerance	Systems Comprehension	Engagement Procedures	Response Selection	Depth Perception
Handling Crisis	Technical Troubleshooting	Meteorology	Organization Skills	Stamina
Disengagement	Decision Making	Aeronautical Terminology	Time Management Skills	
Working Memory	Energy	Flight Rules and Regulations	Critical Thinking Skills	
Initiative	Leadership	Information Orderings	Reasoning Skills	
Concentration/ Selection Attention	Assertiveness	Rate Control Situational Awareness	Problem Solving Skills	
Attention Allocation	Map Reading	Originality	Teamwork Skills	
Task Prioritization	Unit/Command Objectives	Resolving Conflicts	Category Flexibility	
Navigation Skills	Aviation Principles		Helpfulness	
Spatial Orientation	Basic Operation Procedure			
Spatial Visualization	UAS Operations[2]			
Mental Rotation	Arm-handedness			
Communication Procedures				

[2]UAS Operations includes navigation, sensors, and weapons knowledge.

Design Guidance. The Brannick and Levine (2002) method was also used to identify KSAs relevant to performance that SMEs determined should be addressed through system design rather than through training or selection. This list included any KSA that was rated highly on the "Superior from Average" scale (rating of 3 or greater) but not considered "Necessary" or "Practical", and that was rated low on the "Trouble Likely" scale (i.e., not a candidate for training). The only KSAs that met these criteria and were placed in the "design to" category among the 109 KSAs were Flexibility of Closure (i.e., identifying/detecting known patterns [e.g., figure, word, object] that are hidden in other material) and Pattern Recognition (i.e., detecting a known pattern [e.g., a numerical code]; combining and organizing different pieces of information into a meaningful pattern quickly).

The project team is currently adapting the Brannick and Levine (2002) method to include workload ratings tied directly to individual tasks. Workload ratings provided for those UAS Cross Platform JTA tasks during which the AVO has direct interaction with the system (amounting to 188 of the original 256) are currently being evaluated to identify the optimal candidate tasks for incorporation into automation evaluations. These data are currently being collected and will further inform system design guidance.

Implications

Our analysis found a number of general competencies that should be considered when developing selection and training protocols for UAS AVOs in order to avoid costly mishaps. These competencies are ranked by importance to provide cost-benefit guidance to selection and training decision makers. For example, if funding constraints prevent decision makers from implementing a selection test battery that measures all of the KSAs identified in Table 1 then they can at minimum ensure that a sampling of the Tier 1 competencies are utilized. Additionally, our guidance can be used as a gap analysis tool for current UAS selection and training protocols. Decision makers can use this guidance to ensure that their current selection and training protocols include those KSAs identified in our analysis. These protocols can then be updated accordingly depending on the individual programs requirements and funding.

The methodology used for the initial “design to” competency analysis identified two KSAs (i.e., Flexibility of Closure and Pattern Recognition) that SMEs reported cannot reliably be addressed through selection or training. While all other KSAs should be considered during the design process, *Flexibility of Closure* and *Pattern Recognition* should be considered critical from a GCS design perspective as they adhere to the principles of HSI. For example, the literature has shown that systems can be designed to allow operators to more easily recognize patterns to improve the quality of their decision making and performance (Cummings, Bruni, Mercier, & Mitchell, 2007). Additionally, we are in the process of expanding our analysis to the task level to provide a more robust set of design guidelines linked to both tasks and KSAs.

Limitations

As previously mentioned our effort sought to provide platform agnostic guidance. However, one must not blindly follow the guidance provided. Selection, training, and system developers must be sure that when developing these protocols and technologies the individual competencies indeed meet their platform requirements. For example, *Wrist-Finger Speed* and *Arm Handedness* were identified as Tier 1 competencies; however, these may only be relevant to UAS platforms that use joystick interfaces.

Moreover, the sample used to develop this guidance was service specific, consisting of seven Navy operators with Group 3-5 experience and may not be generalizable to other services or smaller platforms. Further, it is important to note that these findings are preliminary, as the small sample size warrants the need for additional data points.

Additionally, these rating Finally, further research is necessary to better understand the empirical implications from this guidance. Empirical investigation will provide insight as to whether selecting, training, and designing to these specific competencies will in fact improve operator performance and in turn reduce UAS mishaps.

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