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The two objectives of this study were to 1) evaluate how specific operator characteristics (prior experience in manned and unmanned flight, teamwork, and gaming) influence mission success in unmanned aircraft systems (UAS) operations; and 2) evaluate the potential utility of a performance assessment tool. Mission success was assessed using a modified version of the Situation Awareness Linked Indicators Adapted to Novel Tasks (SALIANT) methodology. Eighteen participants completed a UAS scenario (port security) as part of 9 two-person crews (pilot and sensor operator). Results showed that the SALIANT measure was able to discriminate differences in performance among the UAS crews. Results also revealed significant correlations between the targeted operator characteristics and several of the SALIANT indicators. Findings from this study will be used to refine the SALIANT measure to support future research on how to optimize human performance in this domain.

The use of unmanned aircraft systems (UAS) is increasing at an unprecedented pace, with a broad range of applications including oil and gas exploration, agricultural management, wildfire mapping, weather monitoring, and emergency response (AUVSI, 2013). This trend has created significant human performance challenges such as how to: select and train UAS operators; design UAS control interfaces to minimize errors and avoid costly accidents; and safely integrate UAS into the National Airspace System (e.g., Dalamagkidis, Valavanis, & Piegl, 2008; Williams, 2006). The problems associated with these challenges are many, yet the solutions are presently few (Fern, Shively, Draper, Cooke, & Miller, 2011). Also, UAS crews differ from manned flight crews in crucial ways: crew and aircraft are not co-located; shift changeovers may occur during a mission; crew may be tasked to control multiple aircraft; control and feedback latency is common; lack standardized cockpit design and controls; lack standardized crew qualifications; and lack 'shared fate' with the aircraft (Tvaryanas, 2006). Accordingly, research is critically warranted to investigate these challenges.

Given the high consequence for errors and the high cost for attrition, the issue of UAS operator selection and training, in particular, has recently garnered considerable attention (e.g., Pavlas et al., 2009). To address this issue, this study investigated how specific operator characteristics (knowledge, skills, and abilities or KSAs) influence mission success in UAS operations. Greater experience in the targeted KSAs (prior experience in manned and unmanned flight, teamwork, and gaming) was hypothesized to be correlated with better performance during a simulated UAS scenario. Mission success was assessed using a modified version of the Situation Awareness Linked Indicators Adapted to Novel Tasks (SALIANT) methodology, developed by Muniz, Stout, Bowers, and Salas (1998). SALIANT provides a theoretically-based assessment of the observed behaviors that are indicative of the team process behaviors that support team situation awareness (e.g., how information exchange is used as an input for building team member situation awareness; Milham, Barnett, & Oser, 2000). Thus, another important objective of this study was to evaluate the potential utility of the modified SALIANT as a performance assessment tool.

Method

Participants

Altogether, 18 participants (all males; average age = 25.29 years) participated in this study as part of two-person crews (pilot, sensor operator). Participants were recruited from the Unmanned Aircraft Systems Science (UASS) undergraduate program at a private aeronautical university in the southeastern United States. The UASS degree provides the necessary expertise for graduates to seek employment as pilots/operators, observers, sensor operators, and operations administrators of UAS. Thus, recruiting participants from this subject pool helps to increase the generalizability of the study's findings to real world UAS operations. Participants were either currently enrolled or had recently completed the *UAS Flight Simulation* course, the final capstone course in the UASS program. One crew was dropped from the analysis due to missing data, leaving a total of eight two-person crews. All participants in the study were treated in accordance with the ethical standards of the American Psychological Association.

Materials and Apparatus

Prior to participation in the study, participants were asked to review and complete an informed consent form and a biographical data form that solicited information on the targeted KSAs. Table 1 lists the items surveyed the biographical data form.

Table 1.
Biographical Data Form Items for Targeted KSAs.

KSA	**Item**
Manned Flight Experience	• Do you have any manned aircraft piloting experience? __ Yes __ No If yes, approximately how many hours? ___Hours • Do you have any pilot ratings or certifications? If yes, please list in the space below.
Unmanned Flight Experience	• Do you have any prior experience in operating unmanned systems? __ Yes __ No If yes, which classes have you previously taken? (Check all that apply): AS 220; AS 235; AS 403; AS 473 • How many hours have you spent in open simulation lab? (Not including class time) ___ Hours • Do you have any prior military experience operating unmanned systems? _ Yes _ No If yes, approximately how many hours? ____Hours
Teamwork Experience	• How much team experience did you have before taking part in this study? *None* (0 teams); *Very Little* (1 - 2 teams); *Some* (3 - 4 teams); *Fair* (5 - 6 teams); *Extensive* (> 6 teams) • Give an estimate of the percentage of time spent on teamwork activities as opposed to individual activities in the last week. Include both in-class and outside class activities: 0%; 0% to 20%; 20% to 40%; 40% to 60%; 60% to 80%; > 80%

Gaming Experience	•	Give an estimate of the time spent (in hours) typically playing any type of video or computer game per week. If none, simply write "0" next to that game. *First-Person Shooter* (Halo, COD, Battlefield, etc.); *Racing* (Forza, Need for Speed, etc.); *Role-Playing Games* (Skyrim, Fallout, World of Warcraft, etc.); *Strategy/Puzzle* (Candy Crush, Solitaire, etc.); *Multiplayer/Online Gaming*; *Other* (please specify)

To assess the influence of these KSAs on team performance, the project team leveraged an existing UAS scenario (port security) developed for the *UAS Flight Simulation* course. In the port security scenario, the UAS crew (pilot and sensor operator) must navigate the UAS to a designated location in the harbor, conduct surveillance in the area to detect and identify the targeted vessel, gather information on the vessel, and then return the UAS to base. During each scenario, crews are presented with an emergency (e.g., oil leak, engine failure) requiring dynamic replanning and teamwork to resolve the situation.

In consultation with subject matter experts and the course instructor, the project team created a modified version of the Situation Awareness Linked Indicators Adapted to Novel Tasks (SALIANT) methodology, developed by Muniz et al. (1998) and adapted by Fiore, Fowlkes, Martin-Milham, and Oser (2000). The modified SALIANT included three new categories: Task / Equipment Knowledge, Crew Resource Management, and Mission Monitoring (see Table 2).

Table 2.
Modified SALIANT Indicators (adapted from Fiore et al., 2000).

Category	**SALIANT Indicator**
1. Spatial Orientation	1.1 Demonstrates awareness of location in space
	1.2 Uses available information sources
	1.3 Cross checks information
	1.4 Scans internal and external environment for abnormal conditions, changes, landmarks
2. Cue Sharing	2.1 Provides and requests backup
	2.2 Reports problems
	2.3 Informs others of actions taken
3. Problem Solving	3.1 Locates potential source of problem
	3.2 Resolves discrepancies
	3.3 Anticipates consequences of actions, decisions, and potential problem situations
4. Information Management	4.1 Provides information in advance
	4.2 Adheres to standard communication format
	4.3 Briefs status
5. Task Management	5.1 Takes action at the appropriate time
	5.2 Exhibits skilled time sharing among tasks
6. Task / Equipment Knowledge	6.1 Demonstrates knowledge of tasks
	6.2 Demonstrates knowledge of equipment/systems
	6.3 Commits minimal operational errors and mistakes
7. Crew Resource Management	7.1 Resolves conflicts with teammates
	7.2 Delegates tasks with appropriate feedback
	7.3 Asks clarification questions as necessary
	7.4 Effectively use available resources
8. Mission Monitoring	8.1 Engages in mission planning and dynamic re-planning
	8.2 Recognizes and responds to messages sent to crew

Subject matter experts carefully reviewed the UAS scenario and then mapped the naturally occurring team behaviors associated with the SALIANT indicators onto a chronological checklist based on expectations of how these behaviors would unfold during the course of the scenario. Examples of SALIANT checklist items are shown in Table 3. During performance of the UAS scenario, four subject matter experts completed the SALIANT checklist, with two trained observers per crew.

Table3.
Example SALIANT Checklist Items for Port Security UAS Scenario.

Category	SALIANT Indicator	Checklist Item
Spatial Orientation	Demonstrates awareness of location in space	Pilot raises landing gear at appropriate altitude
Crew Resource Management	Delegates tasks with appropriate feedback	Crew works together to identify emergency
Mission Monitoring	Engages in mission planning and dynamic replanning	Pilot continually updates the emergency mission entry waypoint

Results and Discussion

Given the small sample size and directional hypothesis for this initial study, alpha was set at $p < .05$, one-tailed. As illustrated in Table 4, the SALIANT indicators were able to discriminate differences in performance among the eight crews. Performance across the SALIANT categories ranged from a minimum of 0% to a maximum of 100%. Average scores ranged from 28% to 58%.

Table 4.
Descriptive Statistics for SALIANT Categories.

SALIANT Category	Minimum	Maximum	Mean	Std. Deviation
Spatial Orientation	.4188	.8182	.5490	.1351
Cue Sharing	.3281	.8438	.5800	.1607
Problem Solving	.0000	.7500	.2813	.2720
Information Management	.0833	.7167	.3177	.2229
Task Management	.0000	1.0000	.5158	.2615
Crew Resource Management	.2500	1.0000	.5313	.3010

Note. N = 16 for each category.

Bivariate correlation analysis was conducted between each of the targeted KSAs (flight experience, teamwork experience, and gaming experience) and team performance as assessed by the SALIANT. Significant correlations are reported in Table 5.

Table 5.
Significant Correlations between KSAs and SALIANT Categories.

KSA	SALIANT Category	Correlation
Manned Flight Experience		
Manned Aircraft Piloting Experience	Crew Resource Management	$r\ (16) = .557, p = .0125$
Manned Flying Hours	Crew Resource Management	$r\ (15) = .542, p = .0185$
Pilot Ratings / Certifications	Crew Resource Management	$r\ (16) = .473, p = .032$
Unmanned Flight Experience		
UAS Open-Simulation Hours	Task Management	$r\ (16) = -\ .509, p = .022$
Teamwork Experience		
Team Experience	Task Management	$r\ (16) = .471, p = .0325$
Team Experience	Problem Solving	$r\ (16) = .471, p = .033$

Team vs. Individual %	Problem Solving	*r* (16) = .465, *p* = .035
Gaming Experience		
First-Person Shooter	Spatial Orientation	*r* (16) = .503, *p* = .0235

Results showed a significant positive correlation between Manned Flight Experience and SALIANT indicators for Crew Resource Management (CRM). Participants with greater Manned Flight Experience performed better on the SALIANT CRM items. This result is to be expected since pilots receive CRM training during the course of their flight instruction.

Unexpectedly, results showed a significant negative correlation between Unmanned Flight Experience and SALIANT indicators for Task Management. Participants with greater Unmanned Flight Experience performed worse on the SALIANT Task Management items. It is possible that, without instructor feedback to calibrate their performance, the additional time spent practicing in the simulation during open-simulation training hours was not beneficial for enhancing their skill acquisition.

Results also showed a significant positive correlation between Teamwork Experience and SALIANT indicators for Task Management and Problem Solving. Participants with greater Teamwork Experience performed better on the SALIANT Task Management and Problem Solving items. This finding suggests that crews were able to transfer domain-general team KSAs to coordinate their activities, which, in turn, may facilitate successful task completion.

Finally, results showed a significant positive correlation between Gaming Experience with First-Person Shooter games and SALIANT indicators for Spatial Orientation. Participants with greater experience with these types of games performed better on the SALIANT Spatial Orientation items. This result likely may be due to the requirement for spatial awareness in these types of games where the player is an avatar in a virtual world. In order to succeed, the player must take in all available information to assess their situation correctly.

Conclusion

Results from this study offer initial support for the potential utility of the SALIANT methodology as a performance assessment tool. However, while promising, conclusions drawn from these results are tentative due to the study's small sample size. Thus, future research is warranted to further validate the SALIANT methodology with a larger sample size as well as with an increased number of items for the SALIANT indicators. In addition, although results revealed significant correlations between the targeted KSAs and UAS crew performance, further research in necessary to empirically evaluate the causal nature of this relationship.

In sum, the long-term goal of this research program is to promote successful UAS operations, in both the private and public sector, by optimizing human performance and minimizing human errors. Findings from this line of research may offer insights into the development of personnel selection tools and UAS operator training programs to achieve this goal.

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