Comparison of ability requirements for UAS operators

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UAS became essential part of military equipment as their use contributes to an increase in mission efficiency and safety of military personnel. Due to the lack of knowledge about specific demands created by operating UAS, a study was conducted to empirically analyse aptitude criteria and to develop specific requirement profiles for UAS operating personnel. For this purpose experienced UAS operators answered the Fleishman Job Analysis Survey. Results suggest that general requirements irrespective of operating position as well as position specific requirements both can be deduced. Differences between systems and comparison with operators of manned military aviation will be reported. The results can contribute valuable information about relevant human factors which should be considered in personnel selection of future UAS operators.

Keywords: Unmanned aerial systems, UAS operators, F-JAS, ability requirements

Introduction

Worldwide, the use of unmanned aerial systems (UAS) in military contexts increases steadily as UAS help to fulfil military duties in an efficient way and contribute to an increase in safety of military personnel. For example, US Department of Defense's UAS inventory increased more than 40-fold between 2002 and 2010 (Gertler, 2012). UAS use has increased for various reasons, but they offer two major advantages over manned aviation: They can be deployed for dangerous missions posing a too high risk for manned aircraft or personnel on the ground and they may also be cheaper in procuration and operation than manned aviation (Gertler, 2012). Also Germany's Federal Ministry of Defence recognizes UAS as a key competence in military aviation strategy (Bundesministerium der Verteidigung, 2016).

Since the introduction of unmanned aerial systems (UAS) in the German Bundeswehr, their deployment has steadily grown and therefore the demand for qualified operating personnel. In the German Air Force, operators of HALE/MALE[1] systems are recruited among pilots of manned military aviation. A similar approach was used by the US Air Force until in 2009 separate career fields for UAS operators and sensor operators were established (Rose, Arnold, & Howse, 2013). Advantages of dual careers in manned and unmanned aviation are that the operators have a better understanding of aviation principles, know more about how to safely operate in national and international air space and have increased career opportunities (Rose, Arnold, & Howse, 2013). Disadvantages are that the dual career approach reduces the

[1] HALE = High Altitude Long Endurance
MALE = Medium Altitude Long Endurance

number of pilots available for manned aircraft and training is cost-intensive. As recent research of the US Air Force is showing, the same aptitude measurements that predict success in manned military aviation also predict success in unmanned aviation (Barron, Carretta, & Rose, 2016). But US Air Force UAS operator training still involves phases of manned aviation training, and as Baron, Carretta, and Rose (2016) stated "…ironically, almost all of the RPA pilot training attrition has been based on failures while piloting manned aircraft" (p. 66). Specific knowledge on requirement differences between manned and unmanned aviation is sparse and seldom enriched with empirical data.

Due to increased demand for operating personnel and the lack of knowledge about specific demands created by operating UAS, the German Aerospace Center, Department of Aviation and Space Psychology in cooperation with the German Air Force Centre of Aerospace Medicine currently conducts a study to analyze demands and aptitude criteria of UAS operators in the German Bundeswehr. Aim of the study is the development of specific requirement profiles for UAS operating personnel as well as the identification of possible differences in requirements between unmanned and manned military aviation.

The methodical outline consists of hierarchical steps dependent of one another. It started with job shadowing thus determining the different operating positions of each UAS system and the associated tasks of respective positions. Subsequently as second step, experienced unmanned aerial vehicle (UAV) operators as well as pilots of manned aircraft answered a standardized questionnaire about the requirements and demands of their operating position which will be reported here.

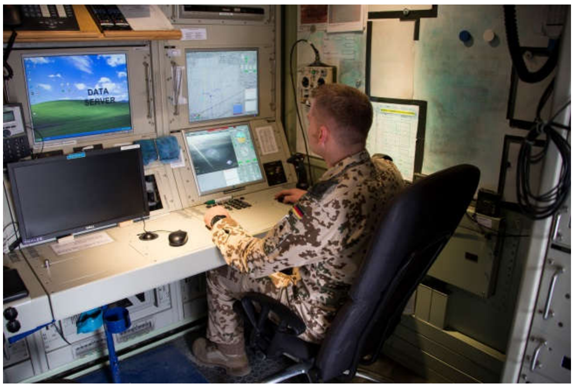
UAS in German military are deployed to fulfil duties in reconnaissance, surveillance and target acquisition missions. The UAS in use in the German Air Force and German Army vary concerning their operational concepts and control systems. Currently, the most important systems (and therefore focused in this study) are Heron 1 in the German Air Force and LUNA, KZO and Aladin in the German Army (see figure 1).

IAI Heron 1 is a medium-altitude long-endurance type UAS which is capable to operate missions up to 24 hours. It needs a runway for take-off and landing and is operated from a ground station by two operational positions (an aerial vehicle operator and a payload operator). The aerial vehicle operator (AVO) is in charge of the flight control of the UAV which is carried out via track ball and keyboard. The UAV can automatically follow navigation points and pre-programmed flight manoeuvers specified by the AVO on a topographic map which is carried out either prior or during the mission. The UAS automatically ensures a stable state of flight. All AVO are pilots already licenced in manned military aviation. Task of the payload operator (PO) is the operating of the camera systems via joystick and mouse. Tracking of targets can be executed automatically but practical experiences show that active control of camera system by PO is necessary for a reliable tracking. Good communication between PO and AVO on position, routing and altitude of UAV is essential for realising effective video information gathering and reaching mission objectives.

EMT Luna (short for German "Luftgestützte unbemannte Nahaufklärungs-Ausstattung", airborne unmanned equipment for close reconnaissance) is an motor glider UAS for close reconnaissance missions up to 80 km distance from ground control station in altitudes up to 4000 meters. The UAV is launched with a catapult and follows a pre-programmed course which also can be altered in flight via joystick and keyboard. At the end of a mission it automatically lands with the help of a parachute or a landing net. It is controlled by an operator who is in charge for planning, monitoring and altering of flight route, and a sensor operator controls the camera equipment during flight via joystick. Additionally, the sensor operator preliminary evaluates the incoming footage during flight and analyses it conclusively afterwards. Like for Heron 1 system, operator and sensor operator have to communicate efficiently for obtaining good results. Operator and sensor operator usually are cross-trained and licensed for both positions. Prior knowledge in aerodynamics and thermodynamics has been found useful for training and deployment.

Rheinmetall KZO (short for German “Kleinfluggerät für Zielortung”, aircraft for target acquisition) is an UAS for reconnaissance and target acquisition missions up to 3.5 hours duration in altitudes up to 3500 meters with a maximum distance of 100 km from ground control station. It is launched with a booster rocket and lands using an integrated parachute. A crew consists of an operator who is responsible for flight preplanning as well as monitoring and route adapting during flight, and a sensor operator who operates the camera system and analyses the image material. Inputs from both positions are entered via track ball and keyboard. Usually, operators are cross-trained and licensed for both positions.

Aladin (short for German ”Abbildende luftgestützte Aufklärungsdrohne im Nächstbereich”, airborne reconnaissance drone for close area imaging) is a light, man-portable UAS for reconnaissance and target acquisition missions up to 30 minutes duration with maximum distance of 5 km from ground control station which is a portable computer device. Maximum altitude is 150 m. The aircraft can be launched by hand or with a bungee catapult and is operated via touch screen and joystick by a single operator who monitors the flight, alters the flight route and analyses the image material.



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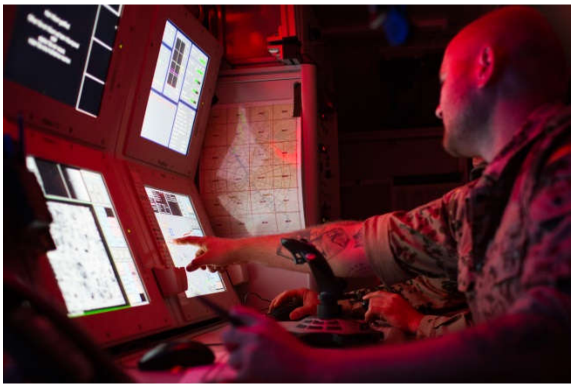

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Figure 1. Ground control stations of Heron (a), Luna (b) and KZO (c) systems, and portable ground control system and UAV of Aladin system.

Requirement profiles will be differentiated for each type of UAS and each operating position (operator/pilot vs. sensor operator) in order to depict UAS specific distinctions, as they differ for example in their level of automation and operating concept as well as concerning their area of operations. Furthermore, differences between manned and unmanned aviation are expected in psychomotor and physical abilities as well due to the high automation level of UAS.

Further aim of the study is to identify position specific requirements as well as abilities and skills which are important for all UAS operators in general, irrespective of specific system or position. Based on the result of the job shadowing phase of the study it is hypothesized that demands in required abilities of sensory or perceptual domain are higher for sensor/payload operators than for operators. Demands in sensory and perceptual abilities might differ between systems due to various video data sources and corresponding perceptual difficulties (visual vs. infrared material).

Method

Experienced UAS operators as well as pilots of manned aircraft answered a German version of the Fleishman Job Analysis Survey (F-JAS, Kleinmann, Manzey, Schuhmacher, & Fleishman, 2010). The F-JAS is a standardized assessment and empirical determines the levels of knowledge, skills, and abilities required to perform a job or task. The F-JAS consists of 73 scales for assessment of abilities and skills from cognitive, psychomotor and sensory, and interactive and social domains. It was extended for two additional scales (operational monitoring and vigilance) which were derived from research projects regarding future requirements in aviation jobs (Eißfeldt, 2016; Eißfeldt et al., 2009). The resulting F-JAS version with 75 scales was licensed by Hogrefe and approved for usage by the German Bundeswehr. Each scale is defined in detail. Subject matter experts use behaviorally-anchored 7-point rating scales to determine how relevant each ability or skill is to their job. According to Kleinmann et al. (2010), sample sizes of more than or equal to 15 F-JAS assessments per occupation are sufficient for reliable results.

More than 300 UAS operators and pilots of manned military aviation have been surveyed with the F-JAS. Additionally, demographic data like age, gender, previous flight experience with unmanned or manned systems was collected. A sample of pilots and weapon systems operators of the Tornado system serves as comparative sample from manned aviation. Table 1 shows sample sizes of assessed operators and demographic statistics like age, gender and flight hours.

Table 1. Demographic statistics and sample sizes and for different aircraft systems and positions.

Type of aircraft	position	*n*	age *M* (*SD*)	% male	Flight hours *Mdn* [range]
UAS					
Heron 1	AVO	22	34.9 (8.6)	100.0	230 [17; 1100]
	PO	22	36.7 (7.7)	95.5	400 [10; 2400]
Luna*	O	43	31.6 (5.4)	95.2	100 [11; 1240]
	SO	38	32.1 (5.2)	94.6	112.5 [8; 1240]
KZO*	O	33	30.6 (5.4)	93.9	72 [3; 400]
	SO	25	31.1 (5.8)	96.0	100 [18; 350]
Aladin**	-	26	28.9 (3.6)	96.2	15 [5; 54]
Manned military aviation					
Tornado	Pilot	21	33.0 (4.9)	100.0	800 [30; 2500]
	WSO	20	34.0 (5.1)	100.0	1300 [20; 2700]

Notes. AVO: Aerial Vehicle Operator, PO: Payload Operator, O: Operator, SO: Sensor Operator, WSO: Weapon System Operator; *Operators of systems Luna and KZO are usually cross-trained for both positions and were surveyed for both positions, deviations between sample sizes result from operators who have not been licensed yet for both positions; **Aladin system requires just one operator.

Results

According to Kleinmann et al. (2010) only scales reaching an average rating ≥ 4 on the behaviorally-anchored rating scale ranging from 1 to 7 should be interpreted as relevant for performing a job successfully as they were evaluated as moderately relevant by experts at least. Concerning domains, mean values ≥ 4 show that requirements in the domain are predominantly evaluated as relevant for the job in question. In domains with mean values below 4, still single scales can be rated as highly relevant for job performance. However, for a first overview, scale means were calculated for each ability domain (see table 2) and were analysed for differences between the systems.

Differences of domain means in UAS operating positions

Operators of the UAS compared differ significantly in domains of cognitive abilities ($F(3, 60.7)=8.99$, $p<.001$; Welsh-corrected *df*), physical abilities ($F(3, 120)=3.01$, $p<.033$), and interactive/social skills ($F(3, 120)=10.67$, $p<.001$). Analysis by Tukey-HSD reveals that Aladin operators evaluated cognitive demands of their operating position as lower than operators of other UAS systems which do not differ from each other. A significant difference was found for physical abilities but general means for this domain are generally low indicating that physical abilities are less important for operating an UAS. Also for interactive/social skills, Aladin operators reported significantly lower demands than operators of other systems. KZO operators reported significantly higher demands in social skills than Heron operators. Descriptive statistics of domains can be found in Table 2. Domain means for Aladin operators are mostly lower than 4 except for cognitive abilities, indicating lower demands for operating this system compared to the other systems. Sensor or payload operators of different systems do not differ significantly in any of the domains.

Table 2. Means and standard deviations for domains.

		O / AVO / Pilot				SO / PO / WSO				
				95% CI				95% CI		
		M	*SD*	lower	upper	*M*	*SD*	lower	upper	*d*
Cognitive Abilities	Aladin	4.12	0.78	3.81	4.44					
	KZO	4.76	0.54	4.57	4.95	4.68	0.40	4.52	4.84	n.s.[1]
	Luna	4.58	0.57	4.40	4.75	4.54	0.68	4.31	4.76	n.s.[1]
	Heron	4.94	0.41	4.76	5.12	4.84	0.67	4.54	5.14	n.s.[2]
	Tornado	5.23	0.46	5.02	5.44	5.25	0.36	5.08	5.42	n.s.[2]
Psychomotor Abilities	Aladin	3.00	1.04	2.58	3.42					
	KZO	3.61	0.84	3.31	3.90	3.66	0.93	3.27	4.04	n.s.[1]
	Luna	3.35	0.93	3.07	3.64	3.68	0.95	3.36	3.99	0.45[1]
	Heron	3.13	1.21	2.59	3.67	4.05	1.01	3.59	4.51	0.82[2]
	Tornado	5.18	0.71	4.86	5.51	4.01	0.94	3.57	4.45	1.41[2]
Physical Abilities	Aladin	1.98	0.90	1.62	2.35					
	KZO	2.57	0.83	2.27	2.86	1.83	0.57	1.59	2.06	1.02[1]
	Luna	2.39	1.12	2.04	2.73	1.93	0.96	1.62	2.25	0.57[1]
	Heron	1.88	1.07	1.40	2.35	1.65	1.22	1.10	2.21	n.s.[2]
	Tornado	4.33	0.76	3.98	4.67	3.72	0.78	3.36	4.09	0.79[2]
Sensory / Perceptual Abilities	Aladin	3.82	0.98	3.42	4.22					
	KZO	3.83	0.67	3.60	4.07	4.06	0.91	3.68	4.44	n.s.[1]
	Luna	3.54	0.75	3.31	3.77	3.74	0.86	3.46	4.03	0.39[1]
	Heron	3.84	0.86	3.46	4.22	4.21	1.07	3.72	4.70	n.s.[2]
	Tornado	5.23	0.55	4.98	5.49	5.16	0.51	4.92	5.40	n.s.[2]
Interactive / Social Skills	Aladin	3.75	0.93	3.37	4.12					
	KZO	4.83	0.63	4.61	5.05	4.69	0.56	4.46	4.92	n.s.[1]
	Luna	4.46	0.75	4.23	4.69	4.42	0.77	4.17	4.67	n.s.[1]
	Heron	4.27	0.61	4.00	4.54	4.70	0.78	4.34	5.06	n.s.[2]
	Tornado	4.80	0.55	4.55	5.06	5.02	0.49	4.79	5.25	n.s.[2]

Notes. AVO: Aerial Vehicle Operator, PO: Payload Operator, O: Operator, SO: Sensor Operator, WSO: Weapon System Operator; *d*: Effect size (Cohen, 1992); [1]Paired sample, contains only operators who evaluated both positions; [2]Independent samples; n.s.: *t*-Test was not significant.

Differences in domain means between operator positions of each UAS

Operating the Aladin system requires just one operator, therefore no position specific differences were analysed. For the KZO system a significant difference in physical abilities was found between positions of operator and sensor operator but domain mean for physical abilities is low, therefore physical abilities are not interpreted as important for KZO operating positions. Also for the LUNA system the difference in physical abilities was found to be significant but also with generally low domain means. Further significant differences between Luna operating positions with small to medium effect size were found for psychomotor (d=0.45) and sensory/perceptual abilities (d=0.39) indicating slightly higher demands for sensor operators than for operators. For operating the Heron system, demands in psychomotor abilities are significantly higher for payload operators than for aerial vehicle operators (d=0.82).

Comparison with manned aviation

As expected, physical abilities seem to be far less important for UAS operators than for operators in manned military aviation (see table 2). For the Tornado system, demands in psychomotor (*d*=1.41) and physical (*d*=0.79) abilities are significantly higher for pilots than for weapon system operators. For psychomotor abilities within Heron operators the contrary effect is revealed with significantly higher demands for payload operators (*d*=0.82). Comparisons of domain means between the Airforce systems Tornado (manned) and Heron (unmanned) show significant differences with higher demands in manned military aviation for all domains except for one domain: Demands in psychomotor abilities for weapon system operators (Tornado) and payload operators (Heron) do not differ significantly.

Table 3. Ability requirements across UAS operator positions

	KZO		Luna		Heron	
	O	SO	O	SO	AVO	PO
General requirements						
20. Selective Attention ^{C}	5.36	5.36	5.23	5.24	5.23	5.90
23. Vigilance ^{C}	5.76	5.48	5.70	5.08	5.82	6.10
58. Dependability ^{I}	5.91	5.84	5.86	5.47	5.72	6.57
72. Perseverance ^{I}	5.70	5.92	5.65	5.68	5.82	6.29
Rather position specific requirements						
8. Problem Sensitivity ^{C}	5.33		5.55		5.41	5.00
21. Time Sharing ^{C}	5.18		5.21		5.64	5.60
22. Operational Monitoring ^{C}	5.73		5.60		5.36	5.52
65. Self-Control ^{I}	5.55		5.40		5.50	5.86
16. Flexibility of Closure ^{C}		5.68		5.66	5.27	6.45
17. Spatial Orientation ^{C}		5.44		5.13	5.59	6.36
18. Visualization ^{C}		5.44		5.45	5.00	5.29
19. Perceptual Speed ^{C}		5.36		5.32		5.62
43. Near Vision ^{S}		5.40		5.16		5.14
69. Achievement Striving ^{I}	5.03	5.24		5.11		5.05
71. Self-Sufficiency ^{I}		5.12	5.23	5.26		5.05

Notes. Only scales ≥ 5 are shown; O: Operator, SO: Sensor Operator, AVO: Aerial Vehicle Operator, PO: Payload Operator; ^{C} Scale from cognitive domain, ^{S} Scale from sensory/perceptual domain, ^{I} Scale from interactive/social domain.

Ability requirements across UAS operator positions

Scales with means ≥ 5 indicate highly relevant demands in abilities for a specific position (Goeters, Maschke, & Eißfeldt, 2004). For the Aladin system, only four scales meet this stricter criterion: Dependability, spatial orientation, far vision, and self-sufficiency. Furthermore, as the Aladin system requires only one operator whose task contains aspects of both, operator and sensor operator positions, it was left out from further analysis. Analysis of all scales with means ≥ 5 for KZO, Luna and Heron shows that they mostly relate to cognitive and interactive/social domain. Generally high requirements for UAS operators (irrespective of operating position or specific system) are found for selective attention, vigilance, dependability, and perseverance (see table 3). Also, requirements rather specific for the position were identified: For UAS operators (irrespective of the operated system) problem sensitivity, time sharing, operational monitoring, and self-control are central abilities with high demands. For sensor operators, demands are higher for abilities like flexibility of closure, spatial orientation, visualization, perceptual speed, near vision, achievement striving, and self-sufficiency. These scales were rated as highly relevant for either operator/aerial vehicle operator or sensor/payload operator among all systems but are not exclusive for one of the operating positions as it can be seen in table 3 that demands for payload operators are high in all scales mentioned above.

Discussion

As expected due to the high automation level in UAS, vigilance and operational monitoring are relevant abilities for UAS operators. Vigilance is highly relevant for both operator positions, whereas operational monitoring seems more relevant for operating positions than for sensor operating positions. This shows again the importance of these scales for future-orientated aviation professions.

As expected from job shadowing phase of the study, operating the Aladin UAS poses lower demands to the operators compared to the other UAS. For the other three systems, high concordance in the required ability domains occurred: For sensor/payload operators of the three systems no differences between the systems were found, indicating that these positions are highly similar throughout the UAS. For the operating position (Aladin system excluded) only minor differences were found in interpersonal/social skill domain (KZO operators reported higher demands than Heron operators). Differences between the operating positions were found for psychomotor and sensory/perceptual domain with a tendency to higher demands for sensor/payload operators than for operators which was expected due to the task allocation of the positions. Summarizing, only minor differences were found between the UAS, but the operating positions do differ. Next steps of analysis will contain a comparison on basis of the single scales to identify possible outlier in the domains.

Highly relevant abilities for all UAS operators irrespective of specific system or position were identified: Selective attention, vigilance, dependability, and perseverance. The identified abilities correspond to results reported by Duvillard-Monternier, Donnot, and Gilles (2012) who analyzed critical abilities for Harfang operators in the French Air Force. Selective attention, dependability, and perseverance were found to be important for all of the three operating positions in a Harfang crew (vigilance was not mentioned to be part of the data acquisition and is not included in the traditional F-JAS with 73 scales). The French Harfang is a UAS highly similar to the German Heron UAS, but the task allocation differs.

Differences between manned and unmanned aviation were expected in psychomotor and physical abilities. Physical abilities are generally low for UAS operators and sensor operators. Demands in psychomotor abilities are lower for UAS operators than for pilots, but for sensor/payload operators they are comparable to those of weapon system operators of the Tornado system. Next steps of the ongoing data analysis will contain comparisons to other systems of manned aviation. Furthermore, it will be analyzed if flight experience has an effect on evaluation of required abilities. Further steps of the study intend the inclusion of data from incident reports and expert workshops to validate the requirement profiles.

The results of this study can contribute valuable information about relevant human factors which should be considered in personnel selection, training, and stress management of future military UAS operators. Especially for personnel selection it can be valuable to identify similarities in requirement profiles for a possible use of synergy potential and a simplification of selection processes. For example, Reeb and Gabauer (2016) found high similarity in the requirement profiles for military air traffic controllers and air battle managers indicating that the use of the same diagnostic tools for the selection processes of both occupations seems reasonable. In the long term, requirement profiles for military UAS operators can also contribute a first hint for selection of civil UAS operators as the demand for qualified personnel might increase with technologic advance and the development of new scopes of applications, for example in agricultural or public safety sector.

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