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Insights on Remote Pilot Competences and Training Needs of Civil Drone Pilots

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Abstract

Remotely piloted aircraft (RPA) operations in civil aviation are not only increasing in number but also in their scope of application, ranging from emergency missions for public authorities to commercial uses such as agricultural spraying. After years of varying levels of in-house training, the continuous growth of RPA operations indicates that qualification and training concepts for civil remote pilots are required. In this novel study undertaken as part of an interdisciplinary research project on civil RPA operations of the German Aerospace Center, remote pilot competences (RPCs) and training needs of professional, civil multicopter pilots in Germany were evaluated. Thirty-eight RPCs covering knowledge, flight skills, cognitive abilities, interpersonal skills, and personality aspects were assessed in an online questionnaire for professional multicopter pilots ($N = 88$). Based on participants' ratings regarding the criticality, difficulty, and frequency of the application of these competences, the RPCs were subsequently classified in terms of their relevance for different stages of training, specifically whether they should be integrated into initial training or additionally be included in recurrent refresher training. For initial training, the majority of key RPCs were found to be related to cognitive abilities and theory knowledge. In contrast, flight skills, personality aspects, and interpersonal skills were considered to be relevant for recurrent training. This study contributes empirical data to previous RPC training recommendations and also promotes the concept of customized recurrent training to ensure safe and effective flight performance.

Keywords: Remote Pilot Competences; Civil drone operations; Unmanned Aviation; Training

1. Introduction

1.1. Background

Civil use of remotely piloted aircraft (RPA) is continuously increasing in quantity as well as in the scope of application. The operations of RPA have also become increasingly complex, such as in operations beyond visual line of sight. Applications of RPA range from emergency missions for public authorities to commercial uses such as agricultural spraying, inspections, or filming. In response to the rapidly increasing civil RPA operations, so is the demand for qualified operating personnel. After years of various in-house training programs without standardized regulations regarding the scope and quality of training, national and international expert panels have initiated efforts to unify the guidelines regarding civil drone pilot accreditation and certification (e.g., JARUS, 2019; ISO, 2021). As an example, in Germany, the Federal Office of Civil Protection and Disaster Assistance recently published training recommendations for remote pilots working in public emergency services (BKK, 2019). To further develop the structure and content of these initial remote pilot training programs, a scientific analysis of the job requirements and training needs of

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professional, civil drone pilots is essential. Furthermore, to represent the operational reality faced by aviation personnel during training, it is important to tailor training topics according to job-specific demands (Malakis et al., 2012). Therefore, evaluating the training needs of professional operators can provide necessary empirical data for future training program improvements.

Previous scientific approaches for remote pilot training involved large-scale research literature reviews regarding RPA operations with the aim of summarizing the potential aptitude criteria for RPA operators (e.g., Pavlas et al., 2009; Torrence et al., 2021). However, the majority of available research literature involves military RPA operations and is therefore not necessarily applicable to civil RPA operations. Whereas military drone pilots operate mostly heavy fixed-wing drones and predominantly work in crews (Doroftei et al., 2020) involving different operating positions such as aerial vehicle or payload operator (Melcher et al., 2018), civil drone pilots currently work mostly in a single operator-single drone scenario involving multicopters.

1.2. Training needs analysis

To evaluate job profiles in aviation, several scientific approaches are feasible, including task analysis, behavioral observation, interviews, and questionnaire surveys (e.g., Melcher et al., 2018). In this study, the Criticality, Difficulty, Frequency model (CDF model; Department of Defense, 2001) was used as a multi-level approach to evaluate RPCs and training needs. The CDF model was previously used in scientific job analyses for operators in intelligent transportation systems (e.g., in traffic management centers) to develop requirement profiles regarding the knowledge, skills, and abilities needed to perform a job successfully and determine the tasks that need to be taught specifically (Pecena et al., 2006; Hinkeldein et al., 2008). The model is used to identify critical training tasks depending on their importance, difficulty, and frequency in a particular occupation. To determine the training needs of individual tasks or competences, the logic of a flow chart is applied (see Figure 1). For example, the more important and more difficult a task is to perform, the more often it needs to be trained by the operator—especially if the task is performed less frequently. After each task or competence is assessed regarding the three levels of performance, the CDF model's flow chart allocates each task or competence to one of three different training categories: *No Training*, *Initial Training,* and *Refresher Training* (cf. Department of Defense, 2001). Competences that are allocated to the *No Training* category do not need specific training but are instead acquired through on-the-job training. In comparison, competences in the *Training* category should be part of initial qualification and training. Finally, competences in the *Refresher Training* category should be part of recurrent and advanced training, as they are used less often but involve difficult and critical tasks, and therefore need to be performed accurately when needed.

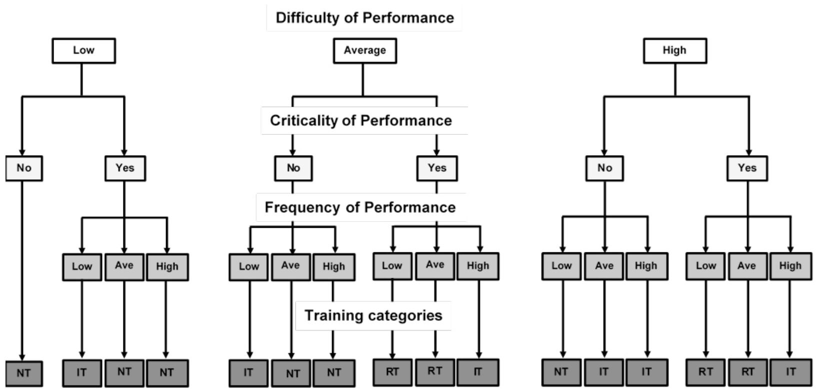

Fig. 1. CDF model flow chart (adapted from Department of Defense, 2001, p. 72; Schmidt et al. 2021).
Notes. Training categories: No Training (NT), Initial Training (IT), Refresher Training (RT).

The RPCs that served as the basis for the training needs analysis in this study originate from a pre-study with 19 subject matter experts including professional remote pilots (Schmidt et al., 2021; see Section 2.1.). As result of the pre-study, 38 key RPCs were determined that were considered essential in order to safely and efficiently perform the tasks of a remote pilot. Based on these RPCs, an online questionnaire was developed for the current study. The goal of the online survey was to investigate the training needs of RPCs among a larger sample of the target population.

2. Material and Methods

2.1. Material

2.1.1. RPC item pool

The 38 RPCs that served as the basis for the online questionnaire originate from a pre-study involving focus groups (Schmidt et al., 2021). The goal of the focus group study was to determine task-based aptitude criteria for civil drone pilots. In the study, 19 subject matter experts were invited as participants who were either civil remote pilots working for public emergency or commercial services, or representatives of public authorities in unmanned aviation departments. Based on critical incident questionnaires involving behavior descriptions, a list of 38 RPCs was compiled that were each rated as important by focus group participants. Concerning the level of precision, the RPCs varied from general competences (e.g., “Spatial orientation”) to specific requirements (e.g., “Taking over manual control of the drone”). The 38 RPCs were divided into the following categories:

- Flight skills (n = 11)
- Theory knowledge (n = 10)
- Cognitive abilities (n = 6)
- Personality aspects (n = 6)
- Interpersonal skills (n = 5)

2.1.2. Online questionnaire

The online survey was conducted in 2019 using the software LimeSurvey (Version 3.24.6, LimeSurvey GmbH). In the first part of the questionnaire, participants were presented with seven socio-demographic questions concerning their occupation and work experience as civil remote pilots (see Section 2.2.). In the second part, participants were asked to assess each of the 38 RPCs on a three-level answer scheme based on the CDF. The three-level answer scheme included a 5-point Likert scale for each of the three CDF performance levels. First, participants rated how frequently they applied the RPC during remote pilot operations (1 = “Never”, 2 = “Rarely”, 3 = “Sometimes”, 4 = “Often”, and 5 = “During every mission”). For each RPC, if participants answered that they “Never” apply it, the subsequent difficulty and criticality scales for this item were canceled. Otherwise, when entering a value of 2 to 4 (“Rarely” to “Often”), the participants were then asked to assess the difficulty of this RPC in comparison to other remote piloting tasks (1 = “Very easy”, 2 = “Easy”, 3 = “Moderate”, 4 = “Difficult”, and 5 = “Very difficult”). Concluding, participants were asked to judge the importance as a remote pilot of being able to perform the RPC (1 = “Unimportant, no impact on drone operation”, 2 = “Rather unimportant”, 3 = “Advantageous”, 4 = “Important”, and 5 = “Very important, crucial for drone operations”).

2.2. Sample

The distribution of the survey targeted civil multicopter pilots who currently work as a drone pilot in a professional context (full-time, part-time, or honorary) in Germany. Out of 100 respondents who completed the entire online questionnaire, data sets for 88 participants were available for data analysis. Twelve participants were excluded from the analysis as they did not meet the criteria of the target sample because they were recreational drone users and pilots of drones other than multicopter-style RPA. Of the remaining 88 subjects, 34 worked as multicopter pilots for emergency services, 40 for commercial or industrial services, 10 in the field of research, and 4 worked as multicopter pilots in other fields (e.g., honorary post involving animal rescues). The remote piloting operational experience varied from 10 hours to 4,000 hours with a median of 122.5 hours (IQR = 50 – 375). On a 5-point Likert scale ranging from 1 = “very little experience” to 5 = “very skilled and experienced”, the participants assessed themselves to be rather experienced when operating a multicopter (Mdn = 4). Regarding the distribution of take-off weight of operated multicopters, the sample’s median was 2.2 kg (IQR = 1 – 5 kg).

3. Results and Discussion

3.1. Results

To determine the classification of each RPC on the three scales of the CDF model, median values were used (see Table 2, Annex A). Based on participants’ ratings on the difficulty scale, the majority of the 38 RPCs were classified as average difficulty of performance (Mdn = 3, n = 26). Two RPCs were ranked as low difficulty (Mdn = 2, n = 2), and 10 RPCs at high difficulty of performance (Mdn = 4, n = 10). The distribution of medians on the criticality scale indicated that all RPCs were rated as rather important or higher by the majority of participants ($Mdn \geq 4$, n = 38). Therefore, all 38 RPCs were assigned to the subcategory “Yes” (Critical) of the CDF model’s criticality factor (Figure 1), and no competency was assigned to the not critical subcategory. According to the participants’ ratings on the frequency scale, 13 of the 38 RPCs were rated as low frequency ($Mdn \leq 2$, n = 13).

Nine RPCs were ranked at average frequency (*Mdn* = 3, *n* = 9) and 16 RPCs were ranked at high frequency of performance (*Mdn* ≥ 4, *n* = 16).

Following the CDF model's flow chart, 16 RPCs were assigned to the *Initial Training* category, 21 RPCs to the *Refresher Training* category, and 1 RPC to the *No Training* category. Table 1 displays the competences that were classified as *Initial* and *Refresher Training* content. *Initial Training* comprises one flight skill, six theory knowledge-based competences, five cognitive abilities, two personality aspects, and two interpersonal skills. In comparison, *Refresher Training* includes 10 flight skills, three theory knowledge-based competences, four personality aspects and three interpersonal skills. The RPC that resulted in the *No Training* category was "Following checklists", a theory knowledge-based competence.

Table 1. Remote pilot competences in initial and refresher training by category of RPC

Category of Remote Pilot Competence	Initial Training	Refresher Training
Flight skills (*n* = 11)	*1 out of 11:* ▪ Establishing routine procedures (20)	*10 out of 11:* ▪ Flying under poor visibility (11) ▪ Flying under poor weather conditions (12) ▪ Flying beyond visual line of sight (13) ▪ Reacting to operational threats (e.g., birds) (15) ▪ Taking over manual control of the drone (17) ▪ Re-planning during flight (16) ▪ Flying in/between narrow building structures (22) ▪ Flying in narrow surroundings of other drones (23) ▪ Utilization of the "kill switch" (19) ▪ Flying without GPS (14)
Theory knowledge (*n* = 10)	*6 out of 10:* ▪ Application of equipment knowledge (4) ▪ Abiding by aviation law (8) ▪ Task allocation among team members (9) ▪ Utilization of distinct phraseology (5) ▪ Paying regard to battery constraints (21) ▪ Paying regard to air space restrictions (10)	*3 out of 10:* ▪ Paying regard to UAV material limitations (3) ▪ Technical emergency behavior (e.g., rotor failure) (1) ▪ Utilization of emergency landing site (2)
Cognitive Abilities (*n* = 6)	*5 out of 6:* ▪ Three-dimensional perception (33) ▪ Spatial orientation (34) ▪ Distance/range perception (35) ▪ Instrument monitoring (36) ▪ Reaction speed (38)	*1 out of 6:* ▪ Awareness of potential safety hazards (37)
Personality aspects (*n* = 6)	*2 out of 6:* ▪ Preventive risk management (30) ▪ Taking responsibility for own errors (26)	*4 out of 6:* ▪ Managing own performance limitations (e.g., fatigue) (27) ▪ Operating responsibly (18) ▪ Stress management in exceptional situations (32) ▪ Avoiding risk-taking behavior (24)
Interpersonal skills (*n* = 5)	*2 out of 5:* ▪ Team communication and information flow (6) ▪ Inter-team communication (e.g., with other drone pilots) (25)	*3 out of 5:* ▪ Perseverance regarding distractions (31) ▪ Teamwork (28) ▪ Perseverance regarding employer expectations (29)

Notes. Item numbers are listed in parentheses behind the item wording.

3.2. Discussion

Regarding the outcomes of the CDF model's classification process, the content of *Initial* and *Refresher Training* differs regarding the number of competences in the individual RPC categories. As Table 1 shows, *Initial Training* shows a slight accumulation of theory knowledge and cognitive abilities, whereas competences in *Refresher Training* involve a comparably higher ratio of flight skills and personality aspects. The content of *Refresher Training* illustrates that particularly the competences that involve the handling of critical events (e.g., handling of distractions, flying in narrow surroundings) and emergencies (e.g., utilization of the kill switch, taking over manual control, stress management in emergency situations) need to be trained more frequently than elementary RPCs in the *Initial Training* section. Emergency situations occur unpredictably as they are often caused by external safety hazards (e.g., weather, other air space entrants). Therefore, essential competences should be over-trained such that remote pilots are prepared to safely and efficiently manage emergencies or surprising events whilst avoiding mistakes. As previous studies on training of aviation personnel have shown, "Instructional methods, such as training needs analysis, […] are necessary to ensure mastery and evaluation of emergency response skills." (Malakis et al., 2012, p. 75). The RPCs in the *Refresher Training* category also reflect issues related to technical performance limitations of RPA (e.g., taking over manual control, understanding the system's performance envelope); thus, challenges related to human-machine interaction are suggested as a further component for remote pilot training (cf. Pavlas et al., 2009; Mouloua et al., 2019). In addition, the results highlight that performing regular job tasks alone is insufficient to maintain RPCs; instead, frequent recurrent training is necessary to continuously ensure safe performance levels—especially when dealing with critical events.

3.3. Conclusions

This study for the first-time evaluated key remote pilot competences (RPCs) and training needs of professional civil drone pilots on an empirical basis in Germany. The results highlight the importance of certain key skills for training and flight performance, thereby improving future selection and qualification processes, as well as training concepts for civil remote pilots. For example, personality aspects and interpersonal skills are areas of competence that add to Human Factors issues of previous remote pilot qualification recommendations (JARUS, 2019; ISO, 2021).

Furthermore, the results support a training approach that involves recurrent refresher trainings that are tailored to operators' needs. Recurrent training not only enhances skill retention but also allows instructors to focus the training content on skills, knowledge, and abilities that are required in remote pilots' operational duties.

As training needs might vary depending on the operating conditions, equipment, task properties, or team composition (cf. Doroftei et al., 2020), feedback loops are important in the training process to provide the trained personnel opportunity to voice additional training needs. Additionally, it is important to re-evaluate RPCs and operators' training needs at regular intervals, as operational reality might change in the future, e.g., from single operator-single drone to single operator-multiple drone or multi-operator multi-drone settings.

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Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Appendix A. Descriptive Statistics

Table 2. Descriptive statistics of remote pilot competences (RPCs)

RPC	**Criticality**				**Difficulty**				**Frequency**			
Item no.	*Mdn*	*M*	*SD*	*N*	*Mdn*	*M*	*SD*	*N*	*Mdn*	*M*	*SD*	*N*
1	5	4.51	.78	81	4	3.8	.94	81	2	2.45	.97	88
2	4	4.04	.88	69	3	2.84	.83	69	2	2.2	1.05	88
3	4	4.05	1	58	3	3.16	.89	58	2	2.39	1.33	88
4	4	3.92	.98	78	3	3.08	.72	78	4	3.44	1.36	88
5	4	4.06	.84	78	3	2.99	.86	78	4	3.55	1.3	88
6	4	4.23	.82	82	3	2.59	.77	82	4	3.59	1.26	88
7	4	4.1	.9	79	2	2	.75	79	5	4.02	1.4	88
8	5	4.47	.75	87	3	3.11	1.02	87	5	4.58	.81	88
9	4	4.24	.64	80	3	2.73	.78	80	4	3.6	1.31	88
10	5	4.57	.76	86	3	2.99	.93	86	5	4.36	1.03	88
11	5	4.34	.91	85	4	3.87	.7	85	3	3.1	.95	88
12	4.5	4.18	.96	82	4	3.63	.87	82	3	2.82	.89	88
13	5	4.21	1.01	62	4	3.81	1.05	62	2	2.36	1.18	88
14	5	4.36	.81	73	4	3.86	.9	73	2	2.44	1.03	88
15	5	4.38	.83	81	3	3.14	.96	81	2	2.45	.88	88
16	4	4.08	.82	77	3	2.77	.81	77	2	2.45	.9	88
17	5	4.64	.6	81	3	3.16	1.12	81	3	2.94	1.16	88
18	4	4.15	.79	61	3	3.1	.94	61	2	2.02	1.06	88
19	4	4.21	.88	34	2.5	2.76	1.1	34	1	1.47	.69	88
20	4	4.17	.86	88	3	2.73	.83	88	5	4.41	.75	88
21	5	4.3	.92	83	3	2.52	.72	83	4	3.98	1.18	88
22	5	4.43	.76	81	4	4.12	.71	81	3	2.76	.96	88
23	4	3.93	.99	54	4	3.67	.89	54	2	1.98	.95	88
24	5	4.52	.71	73	3	3.34	1.04	73	3	3.16	1.49	88
25	4	4.23	.9	74	2	2.45	.85	74	2	2.53	1.07	88
26	4	4.01	1.04	83	3	2.7	1.12	83	4	3.57	1.48	88
27	4	4.15	.97	65	3	2.58	.95	65	2	2.34	1.17	88
28	4	4.01	.75	77	3	2.79	.86	77	3	3.32	1.27	88
29	4	4.18	.8	66	3	3.41	.91	66	3	2.7	1.33	88
30	4	4.08	.82	84	3	3.12	.7	84	4	3.55	1.12	88
31	4	3.91	.91	81	3	2.65	.9	81	3	2.65	.92	88
32	5	4.48	.72	85	4	3.53	.91	85	2	2.69	1.02	88
33	4	3.92	.91	87	3	3.29	.82	87	4	3.81	.96	88
34	5	4.69	.59	88	3	3.34	.97	88	5	4.63	.67	88
35	5	4.55	.68	87	4	3.6	.87	87	4.5	4.2	.95	88
36	4	4.22	.82	85	3	3.39	.74	85	4	3.85	1.16	88
37	5	4.51	.67	85	3	3.41	.79	85	3	3.47	1.21	88
38	5	4.49	.71	88	4	3.65	.79	88	4	3.74	1.01	88

Notes. See Table 1 (Section 3.1.) for the individual item wording.

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