Droning on About Drones—Acceptance of and Perceived Barriers to Drones in Civil Usage Contexts

Chantal Lidynia, Ralf Philipsen and Martina Ziefle

Abstract The word "drone" is commonly associated with the military. However, the same term is also used for multicopters that can be and are used by civilians for a multitude of purposes. Nowadays, drones are tested for commercial delivery of goods or building inspections. A survey of 200 people, laypersons and active users, on their acceptance and perceived barriers for drone use was conducted. In the present work, user requirements for civil drones in different usage scenarios with regard to appearance, routing, and autonomy could be identified. User diversity strongly influences both acceptance and perceived barriers. It was found that laypeople rather feared the violation of their privacy whereas active drone pilots saw more of a risk in possible accidents. Drones deployed for emergency scenarios should be clearly recognizable by their outward appearance. Also, participants had clear expectations regarding the routes drones should and should not be allowed to use.

Keywords Civil drones · Usage contexts · User requirements · Barriers · Technology acceptance · Piloting experience · Human factors

1 Introduction

Sometimes, there are many names for the same concept. Unmanned aerial system, unmanned aerial vehicle (UAV), remotely piloted aircraft system, multicopter, or drone; they all describe the same or at least very similar pieces of airborne technology.

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P. Savage-Knepshield and J. Chen (eds.), *Advances in Human Factors in Robots and Unmanned Systems*, Advances in Intelligent Systems and Computing 499,
DOI 10.1007/978-3-319-41959-6_26

The word "drone," almost regardless of continent, be it Europe, North America, or even Australia, is often associated with the military and even (covert) observation missions or espionage, e.g., [1, 2]. And while this technology has its roots in military and warfare, see, e.g., [3–5], its applications have entered the civilian realm of useful tools and gadgets, especially since the technological development facilitated ever decreasing sizes of drones that are no longer lethal. Consequently, the term "drone" is also used for multicopters that can be and are used by civilians for a multitude of non-threatening purposes. For one, scale model pilots use them as a different kind of remote-controlled model aircraft. Sport enthusiasts document their own outdoor-activities, especially in regard to extreme-sports. Unmanned aerial systems with either rotors or fixed wings are deployed for precision farming, e.g., [6, 7], or wildlife preservation [8].

Additionally, multicopters have attracted the interest of commercial users who plan to deploy these gadgets to transport and deliver goods, e.g., [9, 10], inspect the structural integrity of buildings, e.g., [11], record documentaries or movie sequences, see, e.g., [12], or even send them out in cases of natural disasters to locate survivors or remaining hazards.

All of these different uses have an impact on the general population. The attitude toward and acceptance of unmanned flying aircrafts is instrumental in establishing this technology as valid option for future civilian applications.

As far as the authors of this paper know, up until now, there has been very little research done on human factors that influence the acceptance of this technology. Sandbrook [8] also commented on the lack of research on social factors concerning drone deployment in non-military contexts. For the most part, technological aspects are the focal points of research, e.g., [11, 13, 14]. Of almost equal interest is the legal side of drone usage: Where am I allowed to deploy my multicopter, how much altitude is allowed for these aircrafts, and what zones are completely out of question for me to fly over? This varies considerably across different countries. Even though the European Union has guidelines on civil drone use above 150 kg, each individual nation has instated their own regulations and laws, some more lenient than others, when it comes to UAVs lighter than 150 kg, see among others [4, 15, 16].

2 Related Work

Only little research has been conducted about the requirements that civilians, i.e., the general public, have so that drones or multicopters can be used as non-threatening "helpers" or useful tools. The author of [17] used differently worded questionnaires to gauge the social acceptance of drones as means of cargo or passenger transportation. Her study showed that the information given to the participants had an impact on how this new technology was perceived. The better informed about the risks and possible benefits, the more favorable the acceptance of remotely piloted aircrafts.

In [1], the authors investigated the perception of risks pertaining the comparison of unmanned aerial vehicles and conventionally piloted vehicles in Australia. They came to the conclusion that the risks associated with either type of aerial vehicle did not differ. They also examined if a different naming of the system had any impact on the perceived risk, using the options 'manned aircraft,' 'drone,' 'unmanned aircraft,' 'autonomous aircraft,' and 'remotely piloted aircraft' in their study. Again, they could find no difference in the risk associated with each of these systems.

Boucher, see [2] and [18], has conducted qualitative studies to establish a basis of what people associate when first confronted with the topic of civil drones and their non-military deployment. To do so, he used several focus groups, in the UK and Italy, to get an insight into the first associations people have when asked about drones. Two of the main aspects he found out were that privacy, especially fear of its loss, plays a major role in the perception of drones, and use of drones that yields benefits to others (society, wildlife, etc.) was accepted while benefits to the pilot alone (fun, mementos, etc.) were considered unacceptable and this use needs careful monitoring and regulations.

The overview of existing research showed that although larger payloads, such as passengers or bigger deliveries, are better suited for drones with fixed wings, multi-rotor systems are more readily available and used by hobby and commercial pilots. Also, they possess more maneuverability and require less space for take-off and landing. Therefore, these systems are also more likely to be encountered by laypersons.

So far, there is still a decided lack of research on the acceptance of and requirements for drones and the factors that might influence these concepts. One German research centers on a specific user-group, namely firefighters, and their acceptance of drones as tools for their job, especially disaster management and prevention [19]. It might also be of interest if there are significant differences in the evaluation of drones and drone use by those who actively use it, early adopters still, or those who have had none or only passive exposure to drones, especially considering that technological developments and changes in the legal regulations indicate a spread of drone use in civil contexts in the not so distant future [15]. Therefore, these are the starting points of the present study.

3 Method

The method section is structured as follows: First, the findings from previous focus group studies on which the present work is based will be shortly introduced. Second, the development of the measurement instrument, i.e., the questionnaire, will be presented. Subsequently, there will be a summary of the data acquisition and analyses, followed by a description of the gathered sample.

3.1 Previous Focus Group Studies

In the run-up to the present study, focus group discussions with experienced drone users and laypeople had been conducted, because, apart from diverse privacy concerns, little was known about concrete requirements on and attitudes toward civil drone technology. Consequently, an explorative approach was needed as a first step. The focus groups aimed at identifying potential usage scenarios, requirements on design and control of drones, and perceived barriers and benefits.

Usage Scenarios. Participants distinguished between three usage contexts: (1) drone use as leisure activity, e.g., model flight or private aerial photography, (2) commercial use, e.g., courier services or inspection of large technical installations, and (3) emergency use, e.g., locating missing persons or aerial reconnaissance at disaster scenes. Depending on the scenario, the participants' requirements on drones varied.

Requirements on Drones. Requirements regarding two main aspects of drones could be identified: (1) flight characteristics and control, e.g., the used route, the possible flight radius, or the level of automation regarding the piloting, and (2) identifiability, as in adapting the structural shape and the color to the purpose of use, as well as giving the drone the means to identify itself by, for example, sending an identification code per wireless communication if requested by anyone.

Perceived Benefits and Barriers. Although many advantages of civil drones were mentioned in the focus groups, e.g., pleasure of flying, new perspectives for photography, or access to hardly accessible places, several barriers to drones could be identified that mainly concern privacy issues. In particular, a possible surveillance and unwarranted intrusion into the private sphere were perceived as barrier to acceptance. Also, the overflight of private territory was considered as critical.

3.2 Questionnaire

To quantify the findings from the focus group discussions with a larger sample, a questionnaire was developed. It consisted of four parts, one dealing with user factors and three concerning thematic issues.

Demography and Further User Factors. The first part of the questionnaire collected demographical information, e.g., age, gender, educational level, or occupation. Furthermore, Beier's inventory to measure technical self-efficacy [20] was used to gain an impression of the participants' technical affinities. At last, previous experience with civil drones in terms of usage and passive contact, i.e., having watched flying drones, was gathered for both private and professional contexts.

Evaluation of and Requirements in Different Usage Scenarios. The questionnaire's second section addressed the participants' requirements on drones in three different usage contexts using a within-subject design. Each participant had to

answer questions regarding the requirements on drones in the following contexts: (1) *hobby*, (2) *commercial*, and (3) *emergency*. Short scenario-based introductions with examples derived from the focus groups were given for each context to handle unequal knowledge levels and possible gaps regarding the awareness of concrete purposes of drone use.

The requirements on drones were gathered in a dichotomous way by using questions with polarized, mutually exclusive answer options, whereby one was generally restrictive and one offered more freedom regarding appearance and flights of drones. Table 1 gives an overview of the drone attributes and the related selectable characteristics.

General Evaluation of Civil Drone Technology. The second thematic section dealt with a general evaluation of civil drone technology regardless of a concrete usage scenario. Exemplarily, the following statements used for evaluation shall be mentioned: "*Basically, I find drone technology useful*" or "*What bothers me is that there is no way to identify whether the drone is filming.*" A full listing of presented statements will only be shown in the result section to avoid redundancies. Even numbered Likert-scales (min = 0: "Strongly disagree"; max = 5: "Strongly agree") were used to compel participants to make more differentiated choices.

Barriers. In the last section, participants had to rank several barriers to drones derived from focus groups from 1 ("most important") to 5 ("least important"). The questioned barriers included *violation of privacy*, *pilot's anonymity*, *risk of accidents*, *noise*, and the *missing inference to the purpose of use from the appearance*.

3.3 Participant Acquisition, Data Preparation, and Analyses

The survey was realized as online questionnaire. Participants were acquired at the university, in the social environment of the authors, and by using social networks. In addition, expert forums dealing with civil drones, in particular multicopters, were used to address experienced users.

A total of 253 participants started to fill in the questionnaire. The dropout rate was 20.1 %. Therefore, 53 participants who did not answer at least the first thematic section of the questionnaire were removed from the dataset. The remaining data was

Table 1 Queried drone attributes and given answer options

Drone Attribute	Unrestrictive option	Restrictive option
Form	Customizable	Standardized concerning usage
Color	Customizable	Standardized concerning usage
Flight route	Free choice of user	Approval by authorities
Flight radius	Outside the pilot's visual range	Within the pilot's visual range
Piloting	(Temporarily) autonomous	Permanent human control
Identification	No identification needed	Wireless identification ability

analyzed by both parametric and non-parametric statistical methods. Two-tailed tests were used for significance testing and the level of significance was set to $\alpha = 0.05$.

3.4 Sample

A total of N = 200 participants have completed the questionnaire. 126 (63.0 %) of them were male, 74 (37 %) female. The age in the sample ranged between 15 and 74 years, the mean was 38.21 years (SD = 13.38). The participants' level of education was rather high: the most-often stated educational attainment was a university degree (42.5 %, n = 81), followed by graduation from high school (27.0 %, n = 53) and vocational trainings (23.0 %, n = 46). The remaining participants completed secondary school (9.0 %, n = 18) or had not achieved a school-leaving qualification yet (.5 %, n = 1). 62.5 % (n = 125) of the participants pursued an occupation, while 27.0 % (n = 54) were pupils, students, or apprentices. The technical self-efficacy in the sample was rather high with M = 3.63 (SD = 1.33, scale min = 0, scale max = 5).

Drone Usage. 45 participants (22.5 %) had previously used civil drones in private or professional contexts. The sample's typical drone user is male (95.6 %, n = 43) and has a high technical self-efficacy (M = 4.62, SD = 0.62). Concerning this attribute, the difference between users and non-users (M = 3.35, SD = 1.35) was significant with $t(198) = -6.117$; $p < 0.001$; d = −1.036. In contrast, no significant differences between the user groups could be revealed ($p > 0.05$) regarding age and the level of education. 60.6 % (n = 94) of the non-users stated that they have watched the use of a civil drone at least once before.

4 Results

The presentation of the results is structured as follows: First, the requirements on drones in the three exemplary usage contexts will be presented. Second, the general assessments of and attitudes toward civil drone use will be outlined. The section closes with the presentation of findings gathered from the ranking task.

4.1 Requirements on Drones in Different Usage Contexts

The requirements on drones varied to a great extent depending on the usage context. The differences between them were significant with $p < 0.05$ for all requirements, except where otherwise specified in the following. As can be seen in Fig. 1, a majority of the participants stated that drones in the hobby context can have a

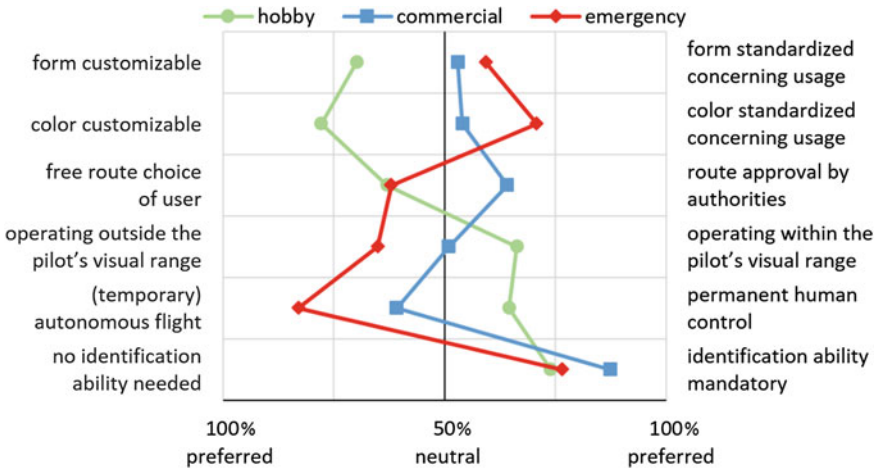

Fig. 1 Percent approval rates of all participants to requirements on drones in different usage contexts

customizable color and form and thus pleaded for unrestrictive rules. In contrast, there was a slight preference for a standardized appearance of commercial and emergency drones. There were no significant differences regarding the latter two use cases on requirements for the drone's form.

Concerning the flight paths, participants would allow both private and emergency drones (n.s. differences) to use routes freely chosen by their pilots, whereas flight plans of commercial drones should be approved by authorities. With regard to the other flight parameters, a reversed response behavior compared to the requirements on the drone's appearance was revealed. More specifically, participants requested more restrictive rules for the flights of hobby drones. They were required to fly within the pilot's visual range and under permanent control of a human pilot. While the participants' opinions regarding these requirements on commercial drones were rather indecisive, a majority stated that emergency drones should be treated less restrictive and be allowed to operate at least temporarily autonomously and outside the visual range of a pilot.

Finally, one requirement was completely independent from the respective usage context (n.s. differences): the drone's ability to identify itself per wireless communication was stated as mandatory by a majority of participants for all contexts.

Concerning previous experience with drones, several differences between users and non-users were revealed in their individual requirements on the usage in the presented scenarios. Most of them were significant with $p < 0.001$. The only exceptions to this trend were piloting in the hobby context; flight radius and color in commercial context; and flight radius, form, and color in the emergency use case, for which users' and non-users' requirements did not differ significantly.

A full overview of users' requests can be found in Fig. 2. A representation of non-users' requirements will be forgone here because it did not significantly differ

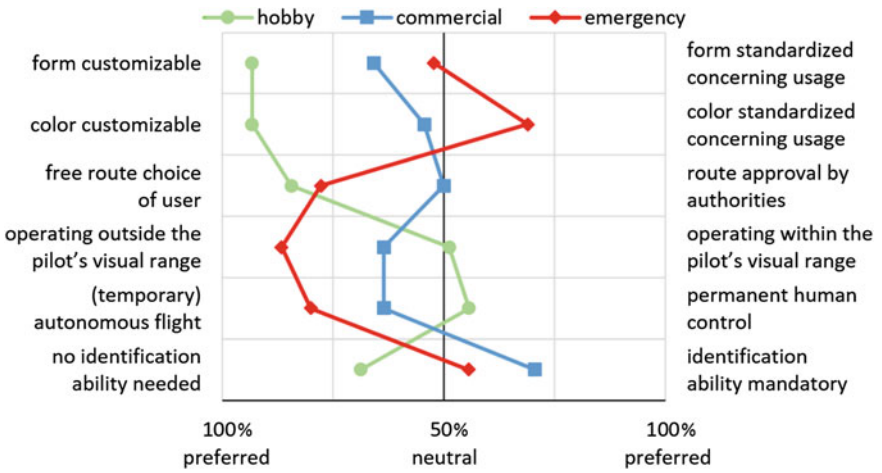

Fig. 2 Percent approval rates of active drone pilots to requirements on drones in different usage contexts

from the total sample (see Fig. 1). Two aspects of users' response behavior stuck out: First, drone users tended to less restrictive requirements. Although the main effects of the scenarios are comparable, the majority of users leaned towards more freedom regarding drones' appearance and flight parameters in all usage contexts. Second, in contrast to non-users, the majority of drone users did not request identification capability in the hobby context, whereas such ability is wanted for commercial and emergency use.

4.2 General Evaluation and Attitudes

The general assessment of civil drone technology revealed that the participants did neither fear injuries from accidents with drones nor drones in general. The fear related statements were the only ones rejected on average. In contrast, for the remaining statements, a rather neutral to slightly consenting attitude must be assumed. This applies in particular to concerns about the anonymity of the pilots, the missing possibility to infer the drone's usage from its looks as well as for the willingness to generally permit drone use and private piloting. Higher approval rates were revealed regarding the unwillingness to accept flights over one's own property, the perceived usefulness of drones, and the wish for identifiability of ongoing film or photography activities. See Fig. 3 for a complete overview of participants' average evaluations.

When looking at the differences between users and non-users, it becomes clear that opinions differ significantly regarding all presented items ($p < 0.001$ and absolute values of Cohen's d >0.7 for all *t*-tests). These differences are particularly evident in

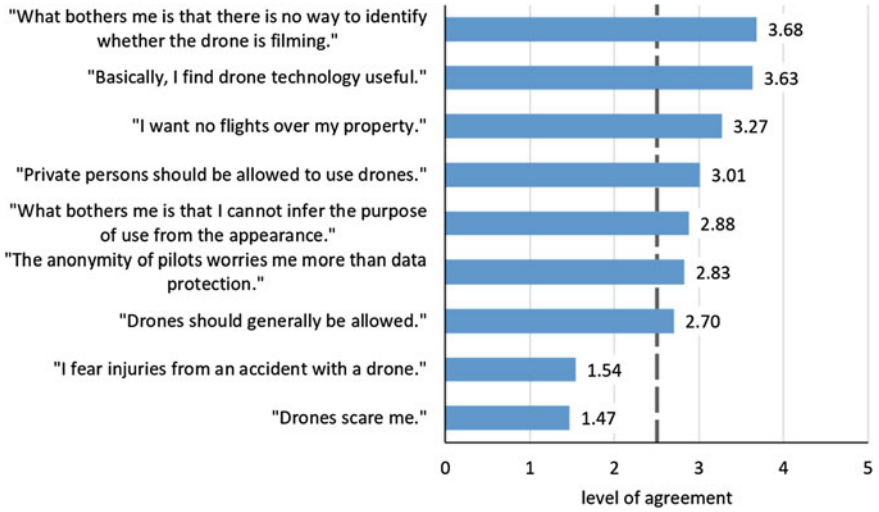

Fig. 3 Average agreement on evaluation statements (min = 0, max = 5). The dashed line indicates the arithmetical neutral level of agreement

the following statements: First, users strongly support the permission of private and general drone use (M approaches the maximum agreement rating), while non-users take a rather neutral position ($t_{general\_use}(196) = -6.566$; $p < 0.001$; d = −1.113 respectively $t_{private\_use}(197) = -7.528$; $p < 0.001$; d = −1.276). Second, users considered the missing identifiability of the pilot, the purpose of use, and ongoing film activities as unproblematic, while non-users are worried about these issues($t_{pilot}(194) = 4.204$; $p < 0.001$; d = 0.72, $t_{purpose}(197) = 6.892$; $p < 0.001$; $d = 1.168$, and $t_{filming}(197) = 9.805$; $p < 0.001$; d = 1.662). Last, non-users do not want air traffic over their private territory, whereas users would allow it ($t_{air\_traffic}(194) = 5.439$; $p < 0.001$; d = 0.924). See Table 2 for the complete comparison of the user groups.

4.3 Barriers

Table 3 gives an overview of barriers to the acceptance of civil drones and their median ranks for the complete sample. The potential *violation of privacy* was revealed as most important and significantly differing from the other barriers (Z = −5.916; $p < 0.001$), followed by the *pilot's anonymity* and *missing possibility to infer the drone's purpose of use from its appearance*. In the latter two cases, there was no significant difference between the barriers' rankings ($p > 0.05$). The *risk of accidents* and the *drone's noisiness* were rated even more unimportant. Although the median ranks of these items did not differ, there was a significant difference concerning the ranking (Z = −3.370; $p < 0.001$);

Table 2 Average agreement on evaluation statements (min = 0, max = 5) and related standard deviations with regard to experience groups

	Users		Non-users	
Statement	M	SD	M	SD
"Private persons should be allowed to use drones." *	4.53	0.97	2.56	1.67
"Basically, I find drone technology useful." *	4.42	0.99	3.40	1.35
"Drones should generally be allowed." *	4.07	1.30	2.30	1.66
"I want no flights over my property." *	2.16	1.80	3.60	1.49
"The anonymity of pilots worries me more than data protection." *	1.98	1.64	3.07	1.50
"What bothers me is that there is no way to identify whether the drone is filming." *	1.93	1.86	4.19	1.18
"What bothers me is that I cannot infer the purpose of use from the appearance." *	1.36	1.76	3.32	1.66
"I fear injuries from an accident with a drone." *	0.80	1.06	1.75	1.60
"Drones scare me." *	0.22	0.60	1.84	1.62

A * indicates significant differences with $p < 0.001$

Table 3 Perceived barriers and median ranks (1 = "most important; 5 = "least important")

Barrier	Median rank
Violation of privacy	2
Pilot's anonymity	3
Missing inference to the purpose of use from the appearance.	3
Risk of accidents	4
Noise	4

Dashed lines indicate significant differences between the ranked items

Table 4 Most and least important barriers with regard to experience groups

Importance	Barrier	
	Users	Non-users
Most important	Risk of accidents (Mdn = 2)	Violation of privacy (Mdn = 1)
Least important	Missing inference to the purpose of use from the appearance. (Mdn = 4)	Noise (Mdn = 4)

Concerning previous experience, privacy loses importance. As shown in Table 4, drone users ranked the risk of accidents as most important barrier, whereas non-users did not differ from the complete sample. Both the *risk of accidents* ($U = 1705$; $p < 0.001$; $r = -0.35$) and the *drone's noisiness* ($U = 2297$; $p = 0.002$; $r = -0.22$) were significantly ranked as more important by users than by non-users. In contrast, the *violation of privacy* ($U = 1973$; $p < 0.001$; $r = -0.30$) and *missing possibility to infer the drone's purpose of use from its visual appearance*

(U = 2068; p <0.001; r = −0.27) were rated more important by non-users than users. There was no significant difference between the user groups concerning the evaluation of the *pilot's anonymity*.

5 Discussion

The ever increasing development of technology for unmanned aerial vehicles and their possible deployment in civil usage contexts prompts questions about the social acceptance of these aircrafts, possible barriers to their use, and likely factors that influence these issues. As current research is still sparse or even nonexistent, the presented study aimed at providing a first insight into the influence of different usage contexts and expertise or prior experience with drone technology on the perceived barriers and requirements people have.

A comparison of different usage scenarios for drones showed that the context of the deployment is important. Different types of usage result in different requirements concerning, for example, looks or flight path. This holds also true for legal regulations that vary depending on the usage context. While this study could not detect a clear position concerning commercially used drones, UAVs used in hobby or emergency contexts evoke clear opinions on what is wanted or needed for their acceptable use. While drones for leisure usage can be less restricted in their look and design, their handling and flight paths are to be carefully observed. For emergency drones, the opposite holds true with their design clearly identifying their purpose but given carte blanche as to where they are allowed to fly.

In general, though, this study could not detect any fear of this technology. On the contrary, its beneficial uses were appreciated. Nevertheless, it was also shown that drones evoke a lot of concerns about the safety of one's privacy, especially in regard to visual recordings, which mirrors results from other studies such as [18].

The factor of expertise, the status of active drone user or non-user, yielded a lot of opposing opinions and results. Non-users are very concerned for their privacy, about who is piloting the drone, and if they are filmed without their knowledge. Although they do not fear the aircraft itself, they are not sure about its use, especially in the hands of hobby pilots. Another big problem for laypeople is the overflight of private property.

Drone pilots, on the other hand, are less concerned for their privacy. They are more worried about the risk of accidents, even though they are more accustomed to the technology. Unsurprisingly, active drone operators have less restrictive requirements on drones in civil usage contexts than the general public with little or no contact to this technology. To facilitate a better acceptance of this novel technology use, in accordance to previous results, [17], a better information of the public and framing of drones is necessary. Clear regulations, which are either recently in place or at least in development, and a more transparent use of drones are needed to satisfy both advocating pilots and concerned laypeople who are warier of unpermitted recordings of their person and property than they are of injuries caused by crashing aerial vehicles.

6 Limitations and Outlook

The questioned sample was rather educated and should have been more heterogeneous. Based on this and the source of acquired participants, the results presented here cannot accurately describe the opinion of the general public. Although possible barriers to civil drone use have been ranked, the results based on this method do not disclose absolute significance. Therefore, further studies need to be conducted. For one, tradeoffs for drone deployment in civil usage contexts should be examined via conjoint analysis: Under what terms are users and/or civilians willing to accept impediments, especially concerning privacy issues? Is it necessary to have information about the pilot's identity or the reason for UAV deployment? How important are personal benefits/advantages?

Furthermore, other user factors such as age (especially the status of digital native or digital immigrant), gender, or the personal attitude concerning privacy and data security should be examined in regard to their influence on the acceptance of UAVs. Does the opinion change when it is no longer only early adopters who use the technology and the people coming into contact with drones are more diverse regarding, for example, gender, education, or technology self-efficacy?

The most controversially viewed possibility of UAVs is that of autonomous flight. Our sample mostly rejected it for hobby pilots and, in Germany it is currently prohibited, but the delivery of goods, for example, would rely heavily on this aspect and, therefore, a change in its acceptance is needed. For this, possible factors could be the pervasiveness but also a more reliable technology to prevent in-air collisions or crashes. This should be examined in further studies.

Another very interesting component is the cultural bias. The present study only included participants from Germany. Other qualitative studies, [2, 18], have already shown different privacy concerns from citizens of the UK, who are used to CCTV surveillance, and Italians, who do not have a lot of CCTV and therefore are a lot more skeptical about drones and the possibility of being filmed or recorded, with or without their knowledge.

Acknowledgments The authors thank all participants for their patience and openness to share opinions on a novel technology. Furthermore, thanks go to Dennis Lohse for his research assistance.

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