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Abstract

In recent years, civil drones have become more and more visible in everyday life. There are numerous reports in the media covering a variety of drone aspects and technical developments. In addition, everyone is used to bird's-eye views as common features in television, movies and photography. However, little is known about how the public perceives this development. This article reports the results of a representative national study on the acceptance of civilian drones. Overall, a balanced but slightly positive attitude towards civil drones was revealed. Factors analyzed include age, gender, place of residence or interest in technical matters, as well as the individual level of knowledge about the topic. Free verbal associations with the general term drone are described as well as concerns about the usage of civil drones. Concerning different applications of civil drones, results indicate clear approval in Germany for the use of drones in civil protection, rescue missions and research work. However, flights for advertising, leisure and parcel delivery purposes are disagreed with by at least half of those questioned. In the presentation of the results, this article describes social acceptance of civilian drones and thus helps to better understand the perception of civil unmanned aerial vehicles.

Keywords Aviation · Drones · Unmanned aerial vehicles (UAV) · Acceptance · Telephone survey

1 Introduction

Drones—understood here as unmanned aerial vehicles (UAV) of a civilian nature—are becoming increasingly visible among the public. Applications range from parcel delivery to animal welfare, from the production of live images of major events to the fight against crime, and from the inspection of industrial facilities to the design of artificial fireworks. Almost monthly, the media reports on new drone use applications and patent applications. Drones help with the construction of ropeways and high bridges, inspect wind turbines, investigate whales on the high seas, and even warn of sharks on a beach. Many drone applications, such as precision farming, are considered to have a high potential for saving resources, thus drone technology is often regarded as having a disruptive quality in certain markets and industries. On a global level, the International Transport Forum of the OECD has described the opportunities and challenges of future drone usage in a recent report [1]. National and international institutions are trying to keep up with the rules and procedures to be established with such dynamic development. The European Commission plans to launch "U-space", an overarching system for unmanned aerial transport, ensuring safe and environmentally sound drone operations in lower airspace. Furthermore, EU-wide rules for drone safety have recently been published as regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July [2].

With the continued strong increase in the use of drones expected by all involved, there is also an increasing interest in the public's perception of this new element. As airport planning has repeatedly shown, a lack of public acceptance can be a limiting factor for further growth in aviation (e.g., [3]). Similarly, certain concerns among the public regarding the use of drones could restrict their wider dissemination. Likewise, existing positive expectations for the use of drones may promote their expansion. This article reports the results of a representative national study on the social acceptance of civilian drones. Therefore, the results help to

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better understand the perception of civil unmanned aerial vehicles.

2 Background

In February 2017, a dedicated Unmanned Aerial Systems (UAS) workshop defined the DLR strategy on UAS airspace integration [4]. Better knowledge about the acceptance of drones among the German population was identified as an important factor for further proliferation of drones in daily life. Results of the study will be the basis of activities designed to increase the acceptance of and to reduce the reservations regarding drones. Finally, the results will help to develop new operational concepts for integrating UAS in airspace with high acceptance from the general public. Literature research yielded a number of published studies. In addition, subsets of items embedded into larger online surveys were sometimes reported. For instance, Pew Research reported that from their American trends panel, 8% of panelists stated they owned a flying drone themselves and 59% stated they have seen someone operating a drone [5]. Miethe et al. [6] published a national study using three different online survey platforms and with 42% found parcel delivery to be the least supported use of drones in all areas of potential drone use in question. The only international study trying to reach representativeness in the context of drone acceptance was a study by the US Postal Service [7]. This study concentrated on the perception of drone delivery in the United States and found the level of interest in drone delivery to be different depending on age group, gender, geographic region, and type of residence.

In Germany, four surveys were identified. Two were launched online specifically in the aviation community and the others were online surveys published by the German Industries Aerospace Association [8] or its association for unmanned aviation [9]. The first study concentrated on the acceptance of different usage with regard to the gender and age of respondents and the perceived need for regulation. The representative online survey launched in October 2017 showed acceptance concerning the civil usage of drones to be evenly shared among participants, with 42% positive and negative for each, and about 15% stating they do not know. Like the 2016 survey, the study confirmed the potential violation of privacy as the highest concern of participants (84%) and showed older respondents and women to be more critical towards civil usage of drones in general.

Lidynia et al. [10] investigated the acceptance of civil drones and perceived barriers for drone use by conducting an online survey developed from previous focus group discussions with experienced drone users and laypeople. Among other things, their study showed that respondents with drone experience were less concerned about privacy and more concerned about the risk of accidents, whereas for non-users, violation of privacy was the highest barrier. In another online survey, the same authors [11] compared various levels of aviation background concerning drone acceptance. This survey found that both non-pilots and aircraft pilots without drone experience were slightly more negative (54%) about drones in general compared to participants with drone experience (including drone-using aircraft pilots) showing high acceptance rates between 67 and 90%. Interestingly, the acceptance of drone flight over one's own real estate was below average for most of the reasons provided above and did not differ with drone experience.

Based on these results, a comprehensive telephone interview survey was proposed, with financing provided by the executive board of DLR.

3 Method

The study was conceptualized in a joint effort of two departments of the DLR, flight guidance human factors (FL-SEG) in Braunschweig and aviation and space psychology (ME-PSY) in Hamburg, resulting in a prototype in February/March 2018 by infas Institute for Applied Social Sciences as a computer-assisted telephone interview (CATI). Using a dual-frame technique with 70% landline and 30% mobile phones, a random digital dial design was used with the aim of obtaining conclusive results representative of the German population.

The questions were asked in a standardized manner by specially trained employees in a telephone interview of approximately 20 min in length. The answers were coded online after each call using an appropriately designed template. For quality assurance, online supervision was performed by senior staff who occasionally listened in. The study fully adhered to the professional code of conduct for telephone interviews agreed upon in Germany [12].

3.1 Sample description

The study was conducted between March and May 2018 and included 832 respondents who answered all the questions. Respondents were 51.8% male and 48.2% female, ranging in age from 14 to 94 years [mean 51.5, standard deviation (SD) 18.2], with a mean household size of 2.5 (SD 1.3). The response rate was calculated as 3.8% following statistical procedures published by the American Association for Public Opinion Research [13], meaning approximately every 25th eligible phone number led to a full interview. Following the same procedures, the cooperation rate for the study was calculated as 9.4% [defined as the percentage of interviews completed divided by the sum of interviews completed (832)

plus the sum of partial interviews (5) plus the sum of refusals (6.952) and the sum of other nonresponses (1.048)].

3.2 Weighting

Educational background and income of the sample were somewhat higher compared to the German population. In addition, the gender distribution according to census information should have been exactly opposite. To compensate for bias in the sample design, infas provided survey weights, which consisted of a probability weight and a calibration. The probability weight itself is composed of a dual-frame weight, which basically integrates the two separate samples from two sample frames into one sample. Therefore, it adjusts the proportion of landline to mobile phone numbers. Additionally, the probability weight controls the different sampling probabilities of persons using one of multiple mobile phone numbers on the one hand and the household size and the amount of different landline phone numbers on the other hand.

Furthermore, the calibration of the survey data refers to recent census data available for Germany concerning age and gender, educational background, size of household, employment status, region and community size. As a consequence, the data were adjusted to provide results generalizable for the German population as a whole [14]. However, in this paper, only raw data will be used to provide a common foundation for data description as well as for explorative analysis. Whenever reference is made to adjusted data, it will be for the purpose of providing population estimates and will be clearly marked.

4 Results

4.1 Associations with the term drone

After explaining the purpose of the study and gaining consent for participation, at the beginning of the interview the respondents were asked whether they knew of the term 'drones' in aviation. 97% participants answered 'Yes' and were subsequently asked an open question to indicate what they associate with a drone. 794 participants gave answers reaching from one single word to several complex sentences, all being protocolled onsite by the interviewer. Later, these qualitative data were coded into six categories: espionage/surveillance/observation (32%), film/video/photo (27%), leisure time/hobby (21%), parcel delivery/transport/air taxi (21%), danger/accident/threat (20%), and military/weapon with 19%. About 18% were coded 'other' indicating a wide range of associations not covered by the aforementioned categories (Fig. 1).

Associations with the term drone
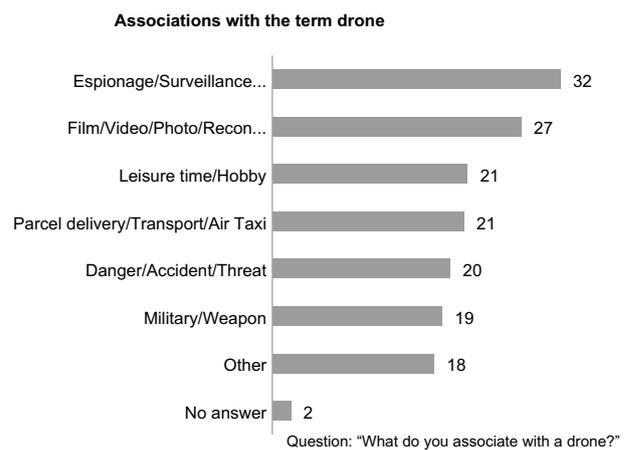
Fig. 1 Associations with the term drone. Results in percent ($N = 794$); multiple answers possible

To provide a view of the diversity of associations, Fig. 2 provides a word cloud [15] of associations reported, showing the top 98 words in alphabetical order. The size and color saturation represent the frequency of the 715 possible words.

4.2 Drone acceptance in German population

After being asked for their associations with the term drone, study participants were informed that the drones referred to in the remainder of the interview were unmanned aircraft that look like small helicopters with several rotors, typically four or more, and that only civil applications were relevant for this study. They were then asked how they would describe their general attitude towards civil drones, specifically, whether it was rather positive or rather negative. In the event they could not decide, the answer was coded as 'undecided'.

Although there was a somewhat even distribution of negative and positive responses to civil drones, there was a slight advantage on the positive side (43% rather negative, 49% rather positive and about 8% undecided). The results vary in accordance with several sociodemographic factors such as gender, age, income and place of residence (Fig. 3).

4.3 Sociodemographic factors of drone acceptance

As can be seen in Fig. 4, subjects who describe themselves as better informed about drones in general have a more positive attitude towards civil drones. The same applies to subjects who describe themselves as having a greater interest in technical matters in general (see Fig. 5).

As reported above, statistical methods were applied to adjust raw data for representativity. With regard to the general attitude towards civil drones, its variation of age and gender will be shown as an adjustment representative of the German
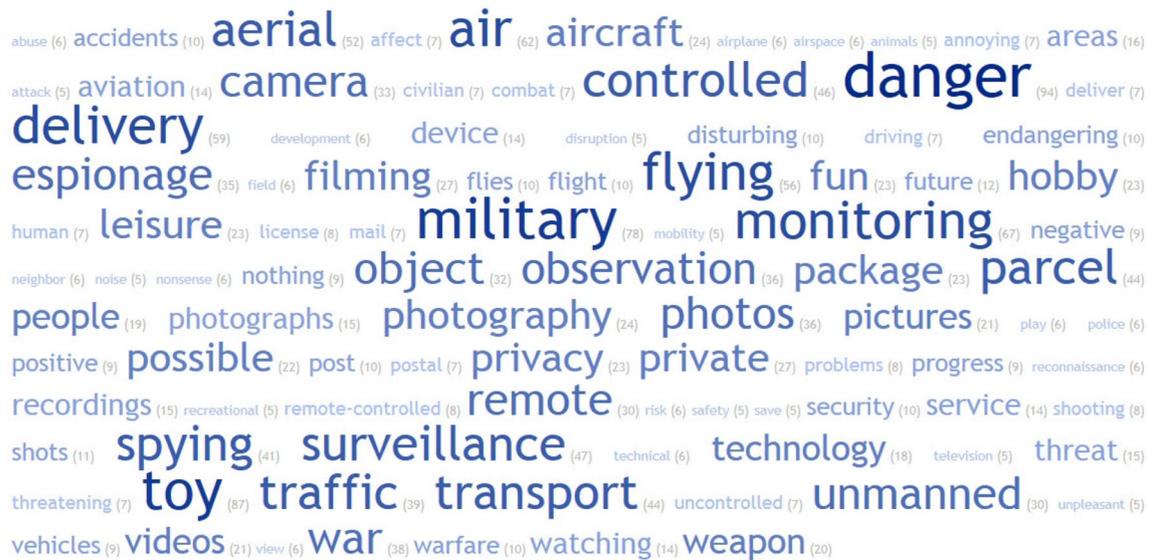
Fig. 2 Associations with the term 'drone'. Word cloud visualization based on frequency
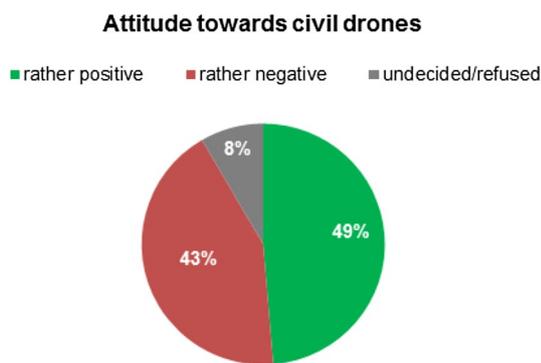
Fig. 3 Attitude towards civil drones
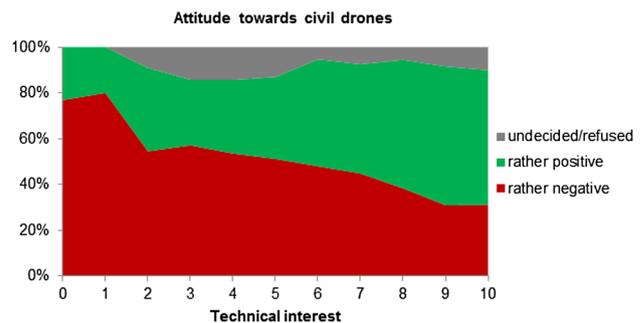
Fig. 5 Relationship between respondent's technical interest and attitude towards civil drones; scale for technical interest ranging from 0 = "not interested" to 10 = "very interested"
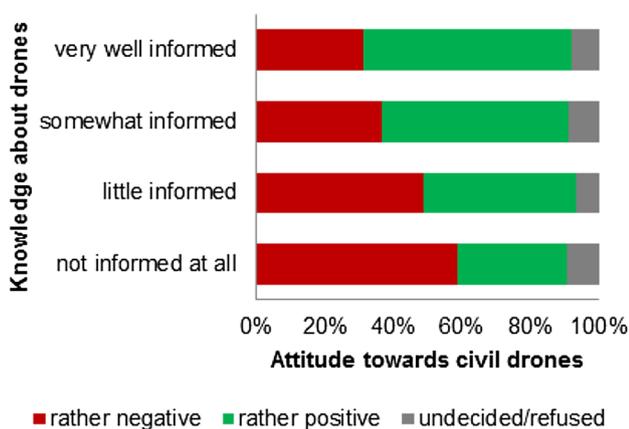
Fig. 4 Attitude towards civil drones based on different levels of knowledge about drones

population (Fig. 6). The adjustment has been made to reflect the age and gender, educational background, size of household, employment status, region, and size of community of the German population. Note that the positive attitudes in the adjusted sample reach 53% and are thus 15% higher than the negative ones.

Male respondents are more positive toward civil drones compared to females. Younger study participants show a higher acceptance than older participants. Interestingly, for senior citizens aged 65 or above, acceptance levels once again reach a level similar to the total sample.

Fig. 6 Attitude towards civil drones. Values in percent; adjusted for representativity
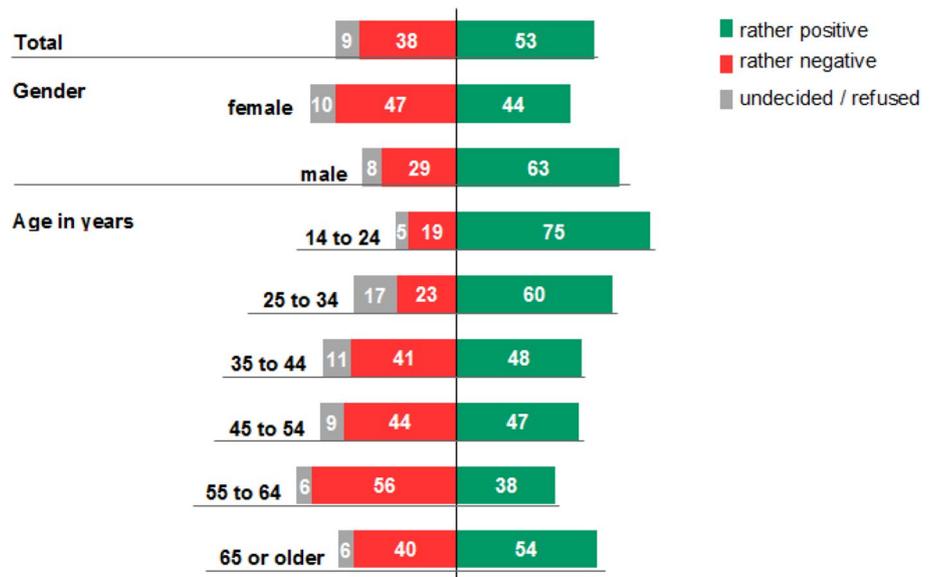
4.4 Areas of concern

4.4.1 Areas of concern with civil drones

Later during the telephone interview, seven different areas of concern that had been identified from the literature were asked in randomized order to avoid sequence effects. When asked to what extent they are concerned about areas of civil drone usage, most of the respondents mentioned the possibility of the abuse of drones for criminal purposes (91%, see also Fig. 7), followed by privacy concerns (86%). Concerns about noise were mentioned less frequently (53%). As a whole, a large majority of respondents named at least three or more subjects of concern regarding civil drone usage (91%). However, the number of aspects mentioned varied with respondent age and gender, with women and older respondents more concerned than younger or male respondents.
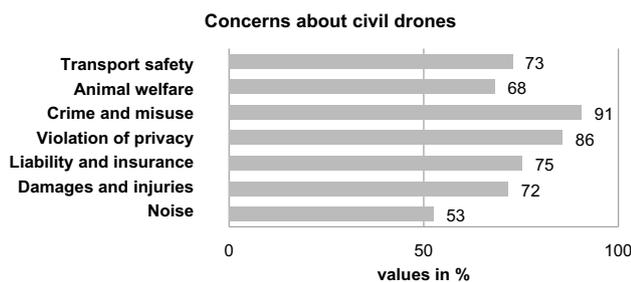
4.4.2 Experience and concerns

About half of the participants (47%) reported having experiences with drones in their personal lives (36.4%), on the job (4%), or in both contexts (6.1%). Looking into the concerns expressed by this group reveals that concerns about accidents, or animal and traffic risks, are significantly less for those having some kind of experience with a drone compared to those having no experience. According to the categorical nature of the variables, Chi-square tests were applied and revealed significant values at the 10% level for concerns about damages and injuries [$\chi^2 (1) = 3.09, p = 0.08$, OR 0.76], animal welfare [$\chi^2 (1) = 4.29, p = 0.04$, OR 0.73], and transport safety [$\chi^2 (1) = 3.39, p = 0.07$, OR 0.75].

Somewhat surprising was the rather low level of concern about drone noise, as this had been discussed in the past as being a potential barrier: 'One potential outcome of scaled-up drone operations is an increase in urban noise volume exceedances above legal or desired limits', p. 39 [1]. However, when looking into information about whether a respondent has or has not reported having yet heard a drone, a higher percentage of noise concerns was revealed: $\chi^2 (1) = 3.29, p = 0.07$, OR 1.45 for those having heard a drone.

The influence of the various concerns on the acceptance of civil drones was analyzed using Chi-square automatic interaction detection (CHAID). This method partitions a contingency table produced from cross-tabulation using a semihierarchical, sequential procedure and has the advantage that it can be used with non-parametric survey data. Of all areas of concerns listed in Fig. 7 being or not being concerned about noise explained the attitude towards civil drones best [$\chi^2 (2) = 38,6, p = 0.000$, OR 0.41]. Following the branches of the decision tree model on the second level,

Fig. 7 Concerns about civil drones

Table 1 Degree of different drone-related concerns and knowledge about drones, *t* test

Topic of concern	Group (1 = rather concerned, 2 = rather not concerned)	*M*	SD	*T*	*p*	Cohen's *d*
Noise	1	2.59	0.88	3.56	<0.001	0.25
	2	2.37	0.86			
Transport safety	1	2.52	0.88	1.05	0.294	–
	2	2.44	0.86			
Animal welfare	1	2.58	0.86	3.96	<0.001	0.30
	2	2.32	0.88			
Liability and insurance	1	2.55	0.87	3.55	<0.001	0.29
	2	2.29	0.88			
Crime and misuse	1	2.53	0.86	3.14	0.002	0.39
	2	2.19	0.92			
Violation of privacy	1	2.53	0.87	2.34	0.019	0.24
	2	2.32	0.85			
Damages and injuries	1	2.57	0.88	4.03	<0.001	0.31
	2	2.30	0.84			

The table shows the medium values of the knowledge about drones participants have. Higher values indicate less knowledge than lower ones. At the same time, the values for knowledge are compared between participants who are concerned about using drones for specific purposes and those who are rather not concerned. For each comparison, the effect size (Cohen's *d*) is given, indicating the practical relevance of significant group differences by relating them to the standard deviation, with *d* = 0.2 representing a small and *d* = 0.5 a medium effect size

among those concerned about noise concerns about transport safety explain the most variance and among those not concerned about noise their concerns about the violation of privacy are the major factor (Table 1).

4.4.3 Knowledge about drones and concerns

Towards the end of the interview, respondents were asked how informed they felt about drones in general. Answers were given on a 4-point Likert scale ranging from 1 = very well informed to 4 = not informed at all. This subjective level of information has been shown to positively correlate with the general attitude towards civil drones, with the higher the subjective knowledge, the higher the acceptance and vice versa (see Fig. 4). Here the focus is on whether people who are concerned about drones or not differ in their subjective level of information or, in short, their knowledge about drones. To compare the two groups, the *t* test was used (Fig. 8).

Results reveal significant group differences for concerns on noise [$t(799) = 3.56$, $p < 0.001$], animal welfare [$t(819) = 3.96$, $p < 0.001$], liability and insurance [$t(812) = 3.56$, $p < 0.001$], crime and misuse [$t(820) = 3.14$, $p = 0.002$], violation of privacy [$t(821) = 2.34$, $p < 0.019$], and damages and injuries [$t(822) = 4.03$, $p < 0.001$]. In each case, respondents who were less informed about drones are more concerned about these issues than those who consider themselves more informed about drones. Only concerning drones being a potential threat to transport safety, no
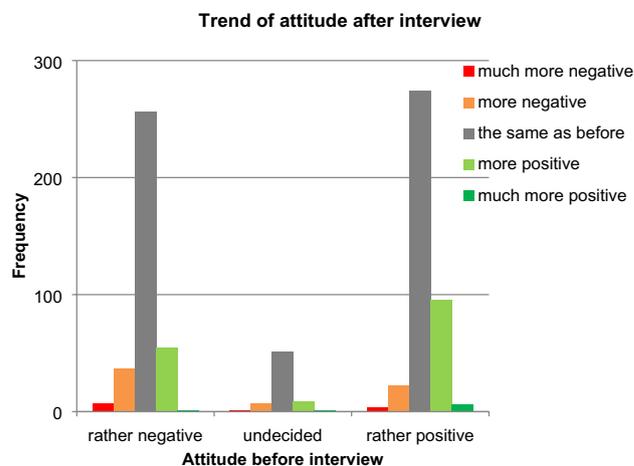
Fig. 8 Trend of attitude towards civil drones after interview

significant group differences were found [$t(810) = 1.05$, $p = 0.294$].

4.5 Acceptance of varying purposes of drone usage

During the interview, the respondents were asked how far they in general would accept various applications of drones, resulting in different levels of agreement. Answers were given on a 4-point Likert scale, ranging from 1 = totally agree to 4 = totally disagree. Acceptance of the various purposes of usage was asked in a randomized order to avoid

sequence effects. Agreement was highest for official uses such as catastrophe response and life-saving efforts and for police and security activities. It was low for leisure time activities and surprisingly low for transport and parcel delivery. Table 2 shows the results in ranked order.

A subsequent question asked respondents for what purposes would they agree to use a drone themselves, again in randomized order: for leisure time activities, first aid, parcel delivery, police and fire service or as an unmanned air taxi. The question concerning own usage of air taxi was formulated as 'unmanned taxi that I would board' to facilitate respondents envisioning such situation and to assure answers were indicating a representative percentage of respondents willing to use air taxi services. Answers were given on the same 1–4 scale mentioned above. To analyze whether this willingness was affected by the respondent's general attitude toward drones, mean values were compared between three groups: participants with a positive attitude towards drones, those not sure, and those with a rather negative attitude. For this purpose, a univariate ANOVA was conducted.

For every type of use, results reveal significant differences between the groups. When using drones for first aid, participants with a positive attitude ($M = 1.59$, SD $= 0.82$) are more likely to make use of a drone than those with a negative attitude ($M = 2.21$, SD $= 1.10$), [$F_{(2, 814)} = 38.71$, $p < 0.001$, $\eta^2 = 0.08$]. Furthermore, respondents who were not sure about their attitude towards drones were more willing to use them in terms of first aid than persons with a negative view. No significant difference between participants with a positive attitude and those who were undetermined was found.

With regard to drone usage for leisure time activities, the statistics show that people who think positively ($M = 2.74$, SD $= 1.07$) about drones are more willing to use them for leisure time activities than people having negative ($M = 3.50$, SD $= 0.78$) or undetermined positions ($M = 3.25$, SD $= 0.90$), [$F_{(2, 825)} = 61.59$, $p < 0.001$, $\eta^2 = 0.13$]. Similar results were

found for the use of drones as unmanned taxis. In this case, participants with a positive attitude ($M = 3.08$, SD $= 0.91$) towards drones are more likely to use them as an air taxi than those with a negative ($M = 3.69$, SD $= 0.60$) or undetermined attitude ($M = 3.42$, SD $= 0.86$), [$F_{(2, 814)} = 56.08$, $p < 0.001$, $\eta^2 = 0.12$].

In terms of parcel delivery, there are significant differences between study participants with positive ($M = 2.65$, SD $= 1.04$) and negative attitudes ($M = 3.44$, SD $= 0.87$) and between those who think negatively about drones and people who are not sure ($M = 3.21$, SD $= 1.02$), [$F_{(2, 824)} = 64.20$, $p < 0.001$, $\eta^2 = 0.13$]. Findings for drones in police and fire service are similar. Results also reveal significant differences between persons with positive ($M = 1.54$, SD $= 0.73$) and negative positions ($M = 2.02$, SD $= 1.02$) as well as between participants with a negative or a neutral view ($M = 1.52$, SD $= 0.75$), [$F_{(2, 816)} = 31.17$, $p < 0.001$, $\eta^2 = 0.07$].

In summary, we can see that in every case, respondents with a positive attitude towards drones are more willing to use them for different purposes, compared to respondents with rather negative attitudes. Also, respondents who are undetermined are often more likely to make use of drones than persons who think negatively about civil drones. Mean values overall indicate that the use of drones for first aid ($M = 1.87$, SD $= 1.01$) and police and fire service ($M = 1.74$, SD $= 0.90$) are the most favorable uses, whereas use as an unmanned air taxi is mostly disagreed with ($M = 3.37$, SD $= 0.84$).

4.6 Overflight acceptance

In October 2017, the "Ordinance for the Regulation of the Operation of Unmanned Aerial Vehicles," [16] was issued in Germany. Concerning these regulations in Germany, similar to flying over groups of people, industrial facilities or public institutions, any overflight of people's homes is prohibited unless the owner has indicated prior consent. In a previous

Table 2 Agreement towards different applications of civil drones, highest agreement on top

Purposes of drone usage	Average agreement (max = 1, min = 4)	Standard deviation (SD)
Catastrophe response	1.43	0.70
Rescue operations, life-saving efforts, civil defense	1.56	0.83
Research purposes	1.59	0.74
Monitoring of infrastructure (transport or energy)	1.82	0.90
Medicine (transport)	1.83	0.98
Agriculture	2.07	1.02
Photo and video recordings for news	2.40	0.99
Leisure time activities	2.62	0.98
Parcel delivery	2.73	1.02
Photo and video recordings for advertising	3.09	0.99

study, Lidynia et al. [10] investigated the acceptance of civil drones and perceived barriers for drone use in Germany. For the 77.5% of their sample that had not used a drone, violation of privacy was the most important barrier to drone acceptance. In their 2018 sample, participants showed disagreement with most of the reasons for a drone's home overflight [11]. The only fully accepted reason was for rescue service operation and even multicopter users would disagree with a stranger's drone flying over their property. The current study shows similar results, indicating participants are concerned about drones flying over their own homes, especially at night. However, for previously accepted purposes of drone usage (see Table 2), primarily official functions of rescue and protection, respondents agreed with drone overflight ($M = 2.2$; SD $= 0.9$).

When questioned about overflights in general during the daytime, results showed less acceptance ($M = 2.8$; SD $= 1.0$). Overflight at night was accepted least, with an average agreement of 3.1, reflecting clear disagreement. Concerning overflight heights, no clear effect of altitude was revealed: regardless of three different heights of overflight (8–10 m, 10–20 m, > 20 m, operationalized as buildings of different amount of floors to clarify during the interview in case of need), respondents showed a clear preference for official functions such as rescue or police. Leisure time activities or parcel delivery received almost no acceptance for overflight of an individual's own property at any of the heights in question.

4.6.1 Population size and overflight acceptance

Also addressed was how the population size of respondent's residences affected their acceptance of drones overflying their homes. Participants were asked about their acceptance of overflights regarding the drone flight purposes they had agreed to previously. In addition, they were asked for their acceptance of overflights in general by day and by night. Answers for acceptance were given on a 4-point Likert scale ranging from 1 = totally agree to 4 = totally disagree. In terms of population size, we used a special system to classify population size: BIK regions [17] are a nationwide regional classification system that describes the urban–rural relationships at community level taking into account the number of employees subject to social security contributions, the population at the place of main residence, and the proportion of commuters. This system represents the cities and their connections to the surrounding areas at community level for conurbations, urban areas and medium- and small-sized centers. Participants were assigned to one of seven BIK region categories, which differ in their population size reaching from less than 2000 to more than 500,000 inhabitants on the basis of their postal code.

Results of an univariate ANOVA revealed significant differences between groups for overflights by day [$F(6, 769) = 2.38$, $p = 0.027$, $\eta^2 = 0.02$] versus by night [$F(6, 772) = 3.29$, $p = 0.003$, $\eta^2 = 0.02$]. However, pairwise comparisons for overflights during daytime indicate no significant differences between individual groups. For overflights at night, significant differences between people living in small towns of 5000–20,000 residents ($M = 3.26$, SD $= 0.84$) and people living in cities of 100,000–500,000 residents ($M = 2.87$, SD $= 1.03$) were shown. Furthermore, results also indicate a significant difference between people who live in towns with 20,000–50,000 residents ($M = 3.27$, SD $= 0.86$) to those with 100,000–500,000 ($M = 3.26$, SD $= 0.84$). In both cases, participants from larger towns show a higher acceptance than participants from smaller towns. For the general acceptance of drones overflying the own house for previously accepted purposes, no significant differences were found between groups [$F(6, 753) = 1.86$, $p = 0.085$].

4.6.2 Population size and acceptance of flying in urban areas

Additionally, how population size influences the acceptance of drones flying in different urban areas was analyzed. Answers were given on a 4-point Likert scale and ranged from 1 = totally agree to 4 = totally disagree. Population size was measured as one of seven BIK regions based on the postal code.

For drones flying in city centers, univariate ANOVA reveals significant differences between groups [$F(6, 754) = 4.13$, $p < 0.001$, $\eta^2 = 0.03$]. Results from respondents who live in villages of less than 2000 residents ($M = 3.43$, SD $= 0.69$) significantly differ from those who live in higher populated towns with 50,000–100,000 residents ($M = 2.90$, SD $= 0.98$), 100,000–500,000 residents ($M = 2.71$, SD $= 0.98$) and with more than 500,000 residents ($M = 2.76$, SD $= 0.94$). Study participants from smaller towns would accept drones in city centers less compared to inhabitants of larger cities (Tables 3, 4).

With respect to drones flying in residential areas, significant differences between the groups were reported [$F(6, 759) = 4.51$, $p < 0.001$, $\eta^2 = 0.03$]. Respondents living in small towns with a population size between 5000 and 20,000 residents ($M = 3.03$, SD $= 0.81$) differ significantly from those living in larger towns consisting of between 100,000 and 500,000 residents ($M = 2.65$, SD $= 1.00$) and cities with more than 500,000 residents ($M = 2.71$, SD $= 0.91$). Furthermore, results shown in Table 5 indicate significant differences between participants living in towns of 20,000–50,000 residents ($M = 3.04$, SD $= 0.94$) and 100,000–500,000 residents ($M = 2.65$, SD $= 1.00$) as well as in cities with more than 500,000 residents ($M = 2.71$, SD $= 0.91$). Again, acceptance from inhabitants in larger

Table 3 Level of drone acceptance and respondents willingness to use different kinds of drone services

Group 1	M	SD	Group 2	M	SD	F	p	Cohen's d
First aid services								
Between groups	–	–		–	–	38.71	< 0.001	0.08
Rather positive	1.59	0.82	Rather negative	2.21	1.10	–	< 0.001	0.64
Rather positive	1.59	0.82	Not sure	1.76	0.97	–	0.354	–
Rather negative	2.21	1.10	Not sure	1.76	0.97	–	0.003	0.42
Leisure time								
Between groups	–	–		–	–	61.59	< 0.001	0.13
Rather positive	2.74	1.07	Rather negative	3.50	0.78	–	< 0.001	0.81
Rather positive	2.74	1.07	Not sure	3.25	0.90	–	< 0.001	0.49
Rather negative	3.50	0.78	Not sure	3.25	0.90	–	0.091	–
Parcel delivery								
Between groups	–	–		–	–	64.20	< 0.001	0.13
Rather positive	2.65	1.04	Rather negative	3.44	0.87	–	< 0.001	0.82
Rather positive	2.65	1.04	Not sure	3.21	1.02	–	< 0.001	0.54
Rather negative	3.44	0.87	Not sure	3.21	1.02	–	0.188	–
Police and fire service								
Between groups	–	–		–	–	31.17	< 0.001	0.07
Rather positive	1.54	0.73	Rather negative	2.02	1.03	–	< 0.001	0.55
Rather positive	1.54	0.73	Not sure	1.52	0.75	–	0.983	–
Rather negative	2.02	1.02	Not sure	1.52	0.75	–	< 0.001	0.51
Air taxi								
Between groups	–	–		–	–	56.08	< 0.001	0.12
Rather positive	3.08	0.91	Rather negative	3.69	0.60	–	< 0.001	0.78
Rather positive	3.08	0.91	Not sure	3.42	0.86	–	0.013	0.38
Rather negative	3.69	0.60	Not sure	3.42	0.86	–	0.044	0.42

The table depicts ANOVA results for comparing different levels of participants' acceptance towards specific drone services as well as their willingness to use them. Small mean values imply that people would like to use drones for that purpose, whereas large values indicate they would not. For between group comparisons η^2 is given as effect size, for pairwise comparisons Cohen's d

towns is higher than those from smaller ones. Additional significant group differences are found for drones flying in commercial areas [$F(6, 754) = 2.73$, $p < 0.012$, $\eta^2 = 0.02$]. In this case, the acceptance of people living in small towns of 5000–20,000 residents ($M = 2.40$, SD $= 0.94$) is significantly lower than the acceptance of people living in large cities with more than 500,000 residents ($M = 2.09$, SD $= 0.87$).

For drones flying in industrial zones, the acceptance is highest for all types of residents, findings reveal no

Table 4 Overflight acceptance for different conditions

Overflight acceptance	Average agreement	Standard deviation
For accepted purposes	2.2	0.9
During the day	2.8	1.0
At night	3.1	0.9

Agreement: 1 = totally agree, 4 = totally disagree, undecided/refused/very different excluded

significant group differences for population size [$F(6, 759) = 1.37$, $p < 0.225$].

4.7 Effect of interview—slightly positive trend of acceptance

For many participants of this survey, the interview was the first time respondents had talked in detail about drones for approximately 20 min. Touching a variety of positive and negative aspects, the general aim of the interview was neither to scare nor to overly convince respondents of drone usage. To control for potential effects, a follow-up question was included at the end asking for a potential change of opinion towards drones due to the interview content.

Evaluation revealed a majority (70%) of stable opinions at the end of the interview, with a slightly higher percentage of subjects with a more positive opinion (20%) rather than a more negative one (10%). This was the same regardless of the respondent's initial statement of acceptance—rather negative, rather positive, or undecided concerning the civil usage of drones.

Table 5 Population size of residence and respondent acceptance of drones flying in different urban areas

Urban area	Group 1	M	SD	Group 2	M	SD	F	p	Cohen's d
City center	Between groups	–	–	–	–	–	4.13	<0.001	0.03
	Less than 2000	3.43	0.69	50,000–100,000	2.90	0.98	–	0.045	0.60
	Less than 2000	3.43	0.69	100,000–500,000	2.71	0.98	–	0.001	0.78
	Less than 2000	3.43	0.69	More than 500,000	2.76	0.94	–	0.001	0.78
Residential area	Between groups	–	–	–	–	–	4.51	<0.001	0.03
	5000–20,000	3.03	0.81	100,000–500,000	2.65	1.00	–	0.005	0.43
	5000–20,000	3.03	0.81	More than 500,000	2.71	0.91	–	0.021	0.35
	20,000–50,000	3.04	0.94	100,000–500,000	2.65	1.00	–	0.013	0.42
	20,000–50,000	3.04	0.94	More than 500,000	2.71	0.91	–	0.048	0.35
Commercial area	Between groups	–	–	–	–	–	2.73	0.012	0.02
	5000 to 20,000	2.40	0.94	More than 500.000	2.09	0.87	–	0.015	0.36
Industrial zone	Between groups	–	–	–	–	–	1.37	0.225	–

Small mean values imply that acceptance is rather high whereas high values mean acceptance is low. For between group comparisons η^2 is given as effect size, for pairwise comparisons Cohen's d

5 Discussion and conclusion

Study results provide an overview of the acceptance of civil drones among the German population. The term "drone" is well known to the population and associations are manifold. The impression, however, is that the necessary distinction between military and civil use of drones can be, and was, made by many of the respondents.

Similar to comparable studies [7, 9, 10], a somewhat consolidated pattern of acceptance was found, as slightly more than four out of ten respondents were rather negative about civil drones, about five indicated a rather positive attitude towards drones, and the rest are yet undecided. Results being a bit more on the positive side than the national survey of 2017 [9] might be due to the CATI method used, which could be more interactive than filling in an online survey. However, it could also be an effect of recent national and international legislation. A more detailed look revealed that the attitude towards drones in a civil usage context has a complex pattern of origins. Amongst other things, it depends not only on gender, age and place of residence, but also on existing interest in technical matters and each individual's level of information about civil drones.

An important influence for the individual's attitude towards civil drones is concerns about noise. Noise concerns rise with personal experience, as those reporting having heard a drone show higher noise concerns than those lacking an acoustic encounter. Furthermore, although reported by only about half of all respondents, among all concerns about usage of civil drones noise concerns have the strongest impact on acceptance. Stakeholders of drone usage thus should invest at maximum on reducing sound emissions to the lowest level possible.

Civil drones have various possible applications: They can be used for leisure time activities and parcel delivery, as well as for life-saving efforts, catastrophe response, or police and security activities. Interestingly, the willingness to use a drone personally is lowest for those uses with the highest economic interest (parcel delivery) and the highest reflection in the news (air taxi). The two uses with the highest acceptance are rescue and public safety, applications in which at least the urban population is already used to from present helicopter overflight. As analysis has shown, respondents with a positive attitude towards drones are more willing to use them for different purposes than those who are more negative. Additionally, respondents who are undetermined are more often likely to make use of drones than persons who think negatively about drone use. This aspect could indicate that those currently undecided about drone acceptance will change over time to a positive attitude, rather than to the opposite. Concerning personal use, the barrier from undecided to a negative attitude seems stronger.

Technical interest in general and knowledge about drones play an important supportive role for acceptance. This finding is in line with prior research: The better people are informed about possible chances and risks, the more they accept the use of drones [18–20]. This aspect could also be reflected in the positive trend found in this telephone interview: providing information on drones led to more positive than negative changes of attitude. However, this trend also shows that the issue of drones is still young and attitudes can still be influenced and to some degree changed, in any direction.

According to models of technology acceptance (e.g., [21]), the attitude toward using a technology is dependent on the perceived usefulness (subjective perception that the application of the technology improves the performance)

and the perceived ease of use (the perception of the necessary effort to learn how to use the application/technology). Both aspects can be enhanced through increased knowledge and experience. The results presented have shown that respondents having personal experience with drones can have significant effects on subjective concerns and overall acceptance, although not always in the form that personal drone experience reduces concerns and improves acceptance. Providing regulations is one way to shape experiences positively, for instance by issuing an overflight ban. Other measures could be to set up strict limits for drone noise emissions and/or operating hours.

The comparison of people's acceptance of drones in different city areas revealed that residents of larger towns show a higher agreement towards drones operating in city centers, residential and commercial areas than inhabitants of smaller towns. Drone operation in industrial areas received highest agreement of all city regions, and no significant group differences for population size were found. A possible explanation could be that in industrial zones fewer citizens are affected. Therefore, drones will probably be first implemented and tested in industrial areas before they will operate at other city regions at later stages of introduction. However for some services like parcel delivery, drones need to approach the residential area from the beginning. For this reason, further investigations should focus on the improvement of social acceptance also for drone applications finding currently only little agreement.

As drones will fly over various areas of a city when traveling to their destination, the organization of urban airspace should be designed carefully taking findings on acceptance into account. Drone traffic could be organized using certain routes following existing infrastructure like rail or highways, with the risk of affecting citizens underneath such corridors even more. An alternative could be a free flight scenario avoiding no-fly zones but sharing the encounter of drone flight among all citizens. Further research should thus figure out the relevant aspects of public acceptance for different layouts of urban air mobility.

All questions in the interviews referred to drones in general. We did not differentiate between diverse drone types as the purpose of the survey was to identify people overall attitude towards unmanned air vehicles. Further research should also consider different drone types and their functions, as this might have an impact on public acceptance. It is imaginable that there are for example higher concerns about drones being equipped for photo recordings as people might fear a violation of their privacy.

However, as recent research has indicated, there are more aspects requiring attention as potential influences on drone acceptance in society include design, noise, and movement patterns [22, 23].

It is likely that the German public is still forming its opinion about civil drones. One way to lead it positively and to further increase the overall acceptance of civil drones could be with the encouragement of information campaigns tailored to specific target groups identified in this study. Further research should focus on the future development of the public's acceptance of civil drones to foster the successful development of U-space and its applications in Germany.

Compliance with ethical standards

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