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User Preferences in Drone Design and Operation

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Abstract: Drones, which were first used in military applications, are now widely used by civilians for various purposes such as for deliveries and as cameras. There has been a lack of research into what drone users expect in terms of drone design and operation from a user perspective. In order to figure out what users want from drones, it is necessary to investigate the perception and design preferences of users with regard to drones. Surveys were conducted to collect data on preferences for various aspects of the design and operation of drone technology. Features relevant to the design and operation of drones were considered. We have identified the underlying factor structures of drone design and operation: outdoor mission type, user interface, military mission type, usefulness, risk, special mission type, and concern. The most important factors that contribute to all the dependent variables are the user interface and usefulness. The fact that drones will be increasingly used in the future is clear; however, the purpose of this study was to find out the areas on which to focus and pay further attention.

Keywords: drones; design; operation; user preference; user interface; usefulness

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1. Introduction

Drones, which were first used in military applications, are now widely used by civilians for various purposes such as for deliveries and as cameras. They have endless possibilities for scientific investigations, emergency response, traffic control, and aerial photography [1]. The drone market has grown steadily and it is predicted that in the future, they will become an indispensable product in our daily lives similar to smartphones [2]. However, despite these prospects, drones are not widely used in our society due to concerns about safety [3,4]. In addition, user-controlled accidents account for a high proportion of drone accidents [5].

Drone-piloting experience using a joystick controller has some problems. The current experience of piloting a drone using a joystick is not intuitive, so it is not well-understood how the drone is operated [6]. In addition, the experience of piloting a drone requires a high mental workload, which can lead to accidents [7]. This could be a big problem in the civilian drone market for users with poor drone-piloting skills. Therefore, it is important to design safe and intuitive ways to interact with aerial systems [8].

Most of the control interfaces for short-range drones utilize radio controller (RC)-based joysticks [9]. However, a lot of skill is required to control the drone using the RC-based control interface [10]. There has been a study that proposed using speech, body position, hand gestures, and visual marker interactions to directly send commands to a drone [8]. Interfaces utilizing a user's natural behavior are more intuitive and easier to learn than interfaces created utilizing communication through machines [11]. In addition, these interfaces are known to require a low mental workload [12]. Therefore, utilizing a more natural interface could solve the problems of the existing drone-piloting experience, such as a lack of intuition, a difficult learning curve, and a high cognitive load.

There has been a lack of research into what drone users expect in terms of drone design and operation from a user perspective. In order to figure out what users want from drones, it is necessary to investigate the perceptions and design preferences of users with regard to drones. Therefore, a survey was conducted on the perception, design, and operation of drones from the perspective of drone users. Surveys were conducted to collect data on preferences for various aspects of the design and operation of drone technology. Features relevant to the design and operation of drones were considered. Our findings will be able to help make drone use more convenient and reduce drone accidents caused by users. Through this, our research is expected to contribute to the popularization and activation of drones.

2. Background

A drone is a flying robot that can be remotely controlled or fly autonomously using software-controlled flight plans; therefore, a drone is considered an unmanned air vehicle (UAV) [13,14]. Drones range in size from vast fixed-wing unmanned air vehicles to smart dust (SD) that consist of many tiny micro-electro-mechanical systems including sensors or robots [15].

Drones are used in a variety of environments. Drone classifications are based on the type of mission (military/civil), the type of flight zone (outdoor/indoor), and the type of environment (underwater/on the water/ground/air/space). A wide variety of drones have been used for military and civilian purposes [15]. Although drones are considered a vital part of military missions, they are also being increasingly used for performing environmental actions, such as managing national parks and agricultural lands, tracking wildlife in different areas, observing the effects of climate change, and monitoring the biodiversity of different ecosystems from rainforests to oceans [16]. Drones can be used for the recognition and investigation of natural disasters including forest fires, avalanches, etc. [17]. Drones can perform both outdoor and indoor missions in very challenging environments [18]. Drones can be equipped with various sensors and cameras for intelligence, surveillance, and reconnaissance missions.

Drones are used for a variety of purposes. Drones can be used for search and rescue missions, environmental protection, mailing and delivery, performing missions in oceans or other planets, and other miscellaneous applications [19]. Drones have been used for military surveillance, planetary exploration, and search-and-rescue in the past few years [20]. One of the environments in which drones can be used is space and the exploration of other planets. Drones can be applied in marine environments to study marine organisms, identify the location of oil spills, and for other military or civilian applications [21–23]. Drones' miscellaneous applications include anti-drones, runway drones, drones that scare birds away from airport runways, window-cleaning drones, gutter-cleaning drones, solar panel-cleaning drones, and hobby drones.

Drones can provide a rapid overview of a target area without any danger. Drones equipped with infrared cameras can provide images even in darkness [24]. Drones can be put into action immediately without any loss of time. Modular drones provide operational benefits in terms of readiness and size. They also have advantages in terms of delivery time and energy consumption compared to non-modular drones [25].

Recently, drone delivery services have become an interesting topic for different companies around the world. Many companies are now using drones to deliver packages to customers. For delivery, the designed drones land and take off vertically and are programmed with the customer's address for delivery of the cargo. Recently, there was a study about consumer preference for drone delivery [26]. Australian people preferred a traditional delivery service over drone delivery, but drone delivery services could become competitive if they are considered faster and cheaper than traditional delivery services.

Human factors should be addressed to improve drone design [27]. A number of options, features, and confusing choices need to be improved [27]. A standardized set of core functions using common terminology is required for drone interfaces [27]. Providing the main functions only for the drone interface makes the operator faithful to the mission [27]. For controlling the drone camera, an uncluttered and efficient user interface (UI) is preferred [28].

Drone-related problems were investigated for drone users [29]. According to their flight experience, there were many problems with user interactions. Controlling drones is seen as difficult. Leisure drones provide a camera function by default. However, with the addition of camera capabilities in drones, users have faced increasing difficulties. They have had to learn to master the drone operation as well as use the camera function [30]. In order to improve the camera function, research on a gimbal system that can reduce vibrations has been conducted [31].

It was found that users experience a significant cognitive load just by controlling RC-based drones. An even higher cognitive load is experienced by users with a drone that includes a camera. This could be a factor that hinders the user experience. An egocentric drone-control interface was proposed to lower the user's cognitive load and as a result, the egocentric drone-control interface outperformed the traditional drone-centric control interface by removing the cognitive load of mental rotation [32]. It is possible to consider a multimodal drone display to provide the pilot with information about the drone's surroundings [33]. Haptic information delivered to the joystick improved situation awareness. Multimodal displays may reduce the cognitive and perceptual workload levels [33].

The guidance, navigation, and control (GNC) of drones are traditionally carried out using three methods, namely radio control, video base, and autopilot [34]. One of the most common ways to control and navigate drones is using a radio-control system. The best way to guide, navigate, and control a drone is an autopilot system. Google glass was applied to control a quadrotor drone using head movements. By using a brain–computer interface (BCI), they made the quadrotor turn, rise, dip, and even fly through a ring [35]. To control and navigate the movement of small drones, smartphones have also been utilized.

Camera drones are receiving increased attention and delivery drones and drone-racing for leisure sports are also gaining interest [36]. In order to popularize drones, relevant regulations or laws need to be revised. However, there are still concerns about the negative side of the spread of drones [29]. Australians were relatively neutral about drones [37]. They did not consider drone technology to be overly unsafe, dangerous, beneficial, or threatening [37]. A lack of knowledge about drones was identified as the biggest concern. Also, privacy, safety, and security were significant public concerns. Nguyen, Manley, and Saidi investigated how drones are being used in public safety operations [38]. They found out that the use of drones in some public safety operations needs to increase.

Therefore, it is necessary to investigate the perception and design preferences of the users of drones. Previously, there were no user-centered studies related to user expectations of drone technology. Therefore, this study will perform a survey related to user preferences of drone design and operation.

3. Study Method

The current study investigates what potential users expect with regard to drone design and operation since user-centered insights have not been well-established. We created questionnaire items related to various issues in drone-related areas from the literature [15,37,39]. The questionnaire consists of two parts (Appendix A). The first part asks about the extent to which the participants have experienced drone technology. The second part contains questions about drone design and operations. A 7-point Likert-type scale was used for the response categories.

Then, surveys were conducted to collect data on preferences for various aspects of the design and operation of drone interfaces. The participants were invited by email or were personal contacts. The voluntary nature of the survey was explained during the process of invitation and no compensation was paid for participation. The participants were given the web page address of the questionnaire and completed it at their own convenience. Features relevant to the design and operation of drones were considered. Various issues in drone-related areas were perceptions of drone technology, applications, interface, and control.

Through factor analysis, the issues related to drone design and operation will be grouped into several categories and multiple regression analyses will be performed to identify the factors necessary for the further popularization of drones.

4. Results

A total of 173 people participated in the survey from May to July 2019. Data from one participant was removed because the participant rated the same score for all items. Of the remaining 172 participants, 129 were male and 43 were female. With regard to their level of education, 52 participants were undergraduate students, 59 held a bachelor's degree, 24 held a master's degree, and 37 held a Ph.D. The average age of the participants was 31.2 years, with a standard deviation of 8.73 (Min = 19, Max = 49). A total of 131 participants were from the College of Engineering and 22 were from Management. The other 19 participants were recruited from science and liberal arts areas (science 8, liberal arts 6, design 4, and no major, 1).

The level of early adopter was neutral (M = 4.2, SD = 1.38). The level of hearing-drone technology was high (M = 5.5, SD = 1.63). The level of knowing how to control a drone and the level of experiencing drone technology were rather low, respectively (M = 3.3, SD = 1.98; M = 3.2, SD = 2.03). Since our focus was to investigate what people expect from drone technology, we did not exclude potential drone users without drone experience from the survey. To sum up, many participants have heard about drone technology but have not had much experience with it.

The internal consistency of the survey responses was assessed by measuring the intercorrelation among the two-paired questionnaire items. The values of Cronbach's alpha for the two-paired features of compatibility and delivery functions were 0.75 and 0.84, indicating that the participants were answering the questions consistently.

The mean and standard deviation for each rating are shown in Appendix B. Since there were so many items, we checked whether dimension reduction could be made by performing principal component analysis (PCA) with the correlation matrix. We obtained seven eigenvalues above the point where the curve starts to level off in a scree plot, which explained 61.20% of the variance. Therefore, the individual items can be grouped into seven factors.

To establish a factor structure and derive important design and operational factors among the many drone technology aspects, exploratory factor analysis was performed. The results of this analysis are shown in Table 1. The seven factors derived were labeled as outdoor mission type, user interface, military mission type, usefulness, risks, special mission type, and concerns.

Factor 1 is a dominating factor that explained 31.4% of the total variance of the data. The first factor, outdoor mission type, includes survey items about people's general perceptions of various outdoor missions that drones can offer. As drones can be used in a variety of outdoor environments, the outdoor mission type was a dominating factor. Factor 2, user interface, contains the survey items asking people's opinions about the drone user interface. Factor 3 consists of the military mission type questions or statements. Factor 4, usefulness, includes survey question items about people's thoughts on drone usefulness. Factor 5 is about the risk issues related to drones. Lastly, Factors 6 and 7 consist of survey items about special mission types and people's concerns about drones, respectively.

The means, standard deviations, and Cronbach's alphas of the factors are listed in Table 2. It shows that all factor items were well-grouped. All factors except for risk have above-neutral (>4) levels, with their means ranging from 4.5 to 5.6. People believe that drone technology can conduct many outdoor missions, military missions, and special missions. The current user interface and usefulness levels are mediocre. People believe that drone technology is not that risky but they still have some concerns.

Table 1. Factor analysis results.

Item Number	Rotated Factor Pattern						
	Factor1	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**	**Factor7**
18	**0.58051**	0.14129	0.29829	0.18243	0.01440	0.03895	0.29160
19	**0.66074**	0.16379	0.37771	0.09782	0.07361	0.09898	0.10496
21	**0.50973**	0.17347	0.22055	0.17077	−0.04194	0.12588	0.38103
28	**0.60638**	0.22438	0.38708	0.18359	−0.01064	0.17462	−0.01864
29	**0.59450**	0.24390	0.27694	0.09267	−0.11973	0.23810	0.26732
30	**0.67305**	0.09209	0.23379	0.30475	−0.02514	0.10006	0.14565
31	**0.82253**	0.15125	0.08977	0.05967	0.04294	0.17182	0.13171
32	**0.76550**	0.16515	0.16819	0.07912	−0.02949	0.24092	0.10310
33	**0.85618**	0.13096	0.17729	0.07390	0.09309	0.18043	0.04625
34	**0.78426**	0.13917	0.07050	0.00594	0.10209	0.22370	−0.01851
36	**0.82153**	0.19672	−0.01443	0.06616	0.10209	0.08474	0.06911
37	**0.80788**	0.19884	−0.09086	−0.00566	0.10099	0.10235	0.02001
38	**0.74703**	0.21540	0.10520	0.10684	0.14839	0.26398	0.03754
45	0.22011	**0.65910**	0.18134	0.14012	0.02192	0.20998	−0.00899
46	0.20637	**0.63776**	0.32202	0.13286	0.06021	0.07088	−0.13414
47	0.25218	**0.72321**	0.31873	0.05612	−0.07713	0.13403	−0.04737
48	0.14274	**0.74136**	0.20577	0.23047	−0.09223	−0.03693	0.17310
49	0.18651	**0.73657**	0.25018	0.13506	−0.09388	−0.02096	0.12309
50	0.15125	**0.79333**	0.05167	0.13027	0.03061	0.14112	0.09679
51	0.14559	**0.65839**	0.05978	0.14050	−0.12534	0.15677	−0.25837
52	0.17287	**0.60020**	−0.00647	0.19214	−0.16439	0.22088	−0.13612
16	0.09169	0.01141	**0.65635**	0.09617	0.05607	−0.00270	0.05269
24	0.15814	0.37096	**0.69304**	0.06606	0.04537	0.19877	0.00784
25	0.19694	0.27910	**0.67789**	0.09292	0.13633	0.21797	−0.15718
26	0.25988	0.30174	**0.68803**	0.16714	0.00681	0.06445	−0.07147
3	0.16631	0.24537	0.12328	**0.63438**	0.02998	0.19190	−0.22658
4	0.19443	0.01340	0.18146	**0.62420**	−0.09167	0.02573	0.11905
8	0.00236	0.20293	0.01055	**0.65065**	0.06637	0.05216	−0.18265
9	−0.03478	0.23252	0.03868	**0.75011**	−0.07970	0.16718	−0.03579
10	0.14145	0.25148	0.29347	**0.58828**	0.13929	0.09074	0.05975
1	−0.02479	0.14085	−0.20787	0.37868	**−0.60480**	−0.04155	−0.09430
2	0.14450	−0.08022	0.18095	−0.08256	**0.63714**	0.01547	0.24078
5	0.01081	0.03857	−0.14457	0.16055	**0.75389**	−0.08031	−0.06839
6	0.01211	−0.05507	−0.27106	0.21590	**0.66892**	−0.18336	0.10796
14	0.24827	−0.16538	0.03950	−0.04306	**0.61840**	0.02059	0.32013
15	0.06304	−0.04685	0.12704	−0.10211	**0.67330**	0.11834	0.09963
39	0.42414	0.01166	0.12089	0.25289	0.06540	**0.51730**	0.02259
40	0.36496	0.33513	0.21849	0.01976	0.10000	**0.51511**	−0.11413
41	0.30574	0.07305	0.13604	0.28482	−0.07393	**0.66121**	0.16045
42	0.32674	0.18405	0.03951	0.13254	−0.06027	**0.73790**	0.04610
43	0.32936	0.26914	0.09471	0.13159	0.00958	**0.75548**	0.07646
11	0.04818	−0.19738	−0.07369	−0.22532	0.32765	−0.02774	**0.53197**
12	0.22976	0.10359	0.02802	−0.03289	0.20016	0.05106	**0.75466**
13	0.24622	−0.04545	−0.03079	0.04905	0.22699	0.16188	**0.76377**

For each factor, bold font indicates the significant component factors.

Table 2. Mean and standard deviation of each factor for drone design and operation.

Factors	Mean	SD	Cronbach's Alpha
Outdoor mission type	5.6	1.11	0.95
User interface	4.8	1.12	0.90
Military mission type	5.2	1.32	0.84
Usefulness	4.5	1.09	0.79
Risk	3.8	1.09	0.79
Special mission type	5.1	1.21	0.85
Concern	4.7	1.32	0.74

To determine which of the seven factors strongly influence the various dependent variables, multiple regression analyses were performed using SAS 9.4. The data we used are the average scores for each factor since each factor contains several items. The seven dependent variables we selected are the intention of buying drones, interest in drone functions, self-vision about using drone technology in 5 years' time, the intention of using drones, the increase in satisfaction in daily life, saving time in daily life, and saving energy in daily life. Table 3 shows the multiple regression results for various dependent variables.

Table 3. Multiple regression results.

Factors	Partial R-Square	Model R-Square	F Value	Pr > F
Prediction for intention of buying drones				
F2	0.3589	0.3589	95.16	<0.0001
F4	0.0383	0.3972	10.74	0.0013
F5	0.0128	0.41	3.65	0.0578
F1	0.0175	0.4275	5.1	0.0252
Prediction for interest in drone functions				
F2	0.371	0.371	100.25	<0.0001
F4	0.0653	0.4363	19.59	<0.0001
F6	0.0314	0.4677	9.92	0.0019
F5	0.017	0.4847	5.51	0.0201
F1	0.0069	0.4916	2.25	0.1354
Prediction for self-vision about using drone technology in 5 years' time				
F2	0.2723	0.2723	63.62	<0.0001
F4	0.0916	0.364	24.35	<0.0001
F6	0.0201	0.3841	5.48	0.0204
F5	0.0145	0.3986	4.04	0.0461
Prediction for intention of use with drone technology				
F2	0.3828	0.3828	105.42	<0.0001
F4	0.0748	0.4576	23.3	<0.0001
F5	0.0177	0.4752	5.66	0.0185
F6	0.0152	0.4904	4.97	0.0271
Prediction for increase in satisfaction in daily life				
F4	0.3829	0.3829	105.48	<0.0001
F2	0.1308	0.5137	45.45	<0.0001
F6	0.0118	0.5255	4.17	0.0426
F5	0.0143	0.5397	5.17	0.0242
Prediction for saving time in daily life				
F4	0.3473	0.3473	90.47	<0.0001
F2	0.0636	0.4109	18.23	<0.0001
F5	0.0143	0.4252	4.17	0.0427
F6	0.0133	0.4384	3.94	0.0487
Prediction for saving energy in daily life				
F4	0.3728	0.3728	101.06	<0.0001
F2	0.0779	0.4508	23.98	<0.0001
F5	0.0165	0.4673	5.21	0.0237
F6	0.0107	0.478	3.41	0.0666

Using the intention of buying drones as the dependent variable and the seven factors as the independent variables, we performed a stepwise regression analysis to select the relevant independent variables. The results of the regression indicated a significant difference for the intention of buying drones regarding four variables ($F(4, 167) = 31.18$, $p < 0.0001$).

R^2 was 0.4275. The four variables that were selected are user interface, usefulness, risks, and outdoor mission type. Obviously, risks were affected negatively.

Using the interest in drone functions as the dependent variable, the results of the regression indicated a significant difference for the interest in drone functions regarding five variables (F(5, 166) = 32.11, $p < 0.0001$). R^2 was 0.4916. The five variables that were selected are user interface, usefulness, special mission type, risks, and outdoor mission type.

Using self-vision about using drone technology in 5 years' time as the dependent variable, the results of the stepwise regression analysis indicated a significant difference for self-vision about using drone technology in 5 years' time regarding four variables (F(4, 167) = 27.67, $p < 0.0001$). R^2 was 0.3986. The four variables that were selected are user interface, usefulness, special mission type, and risks.

Using the intention of using drones as the dependent variable, the results of the regression indicated a significant difference for the intention of using drones regarding four variables (F(4, 167)= 40.17, $p < 0.0001$). R^2 was 0.4904. The four variables that were selected are user interface, usefulness, risks, and special mission type.

Using the increase in satisfaction in daily life as the dependent variable, the results of the regression indicated a significant difference for the increase in satisfaction in daily life regarding four variables (F(4, 167) = 48.96, $p < 0.0001$). R^2 was 0.5397. The four variables that were selected are usefulness, user interface, special mission type, and risks.

Using saving time in daily life as the dependent variable, the results of the regression indicated a significant difference for saving time in daily life regarding four variables (F(4, 167) = 32.59, $p < 0.0001$). R^2 was 0.4384. The four variables that were selected are usefulness, user interface, risks, and special mission type.

Using saving energy in daily life as the dependent variable, the results of the regression indicated a significant difference for saving energy in daily life regarding four variables (F(4, 167) = 38.23, $p < 0.0001$). R^2 was 0.4780. The four variables that were selected are usefulness, user interface, risks, and special mission type.

The variable that had the greatest influence on drone purchase and the intention to use drone technology was the user interface. Therefore, we can increase the intention to purchase and use drones through the improvement of the user interface. Also, the variable that most affects the daily use of drones was usefulness. It was found that the usefulness needs to be increased in order to use drones in daily life more. In addition, risks and special mission type were also influential factors. If the risks of using drones are reduced and the special mission types of drones are provided, greater utilization will occur in daily life.

5. Discussion & Conclusions

One-hundred and seventy-two subjects participated in the preference survey to investigate what potential users expect with regard to drone design and operation. We have identified the underlying factor structures of drone design and operation: outdoor mission type, user interface, military mission type, usefulness, risk, special mission type, and concern. From multiple regression analyses, four main factors for drone-buying intention were derived. They are user interface, usefulness, risk, and outdoor mission type, which explained 42.75% of the variance that accounts for users' drone-purchasing intentions. The most important factors are user interface and usefulness, which account for 39.72% of the total variance contributing to drone-purchasing intention. By identifying these, we are able to provide drone designers and manufacturers with the advice that the user interface and usefulness factors should receive the most attention for achieving drone technology success.

From regression analyses, five main factors for interest in drone functions were derived. They are user interface, usefulness, special mission, risk, and outdoor mission type, which explained 49.16% of the variance that accounts for users' interest in drones. Again, the most important factors are user interface and usefulness, which account for 43.63% of the total variance contributing to interest in drones.

From regression analyses, four main factors for self-vision about using drone technology in 5 years' time, drone use intention, increase in satisfaction in daily life, saving time in daily life, and saving energy in daily life, were derived. They are user interface, usefulness, risk, and special mission type, which explained 39.86%, 49.04%, 53.97%, 43.84%, and 47.80% of the variance. The most important factors are user interface and usefulness, which account for 36.40%, 45.76%, 51.37%, 41.09%, and 45.08% of the total variance.

The most important factors are user interface and usefulness, which contribute to all the dependent variables. They should be improved and garner more attention to achieve the popularization and success of drones. The most important factor in the intention to buy drones, interest in drone functions, self-vision about using drone technology in 5 years' time, and intention of using drones is user interface, whereas the most important factor in the increase in satisfaction in daily life, saving time in daily life, and saving energy in daily life is usefulness. User interface must be improved to allow users to buy and use drones, and the usefulness of drones must also be enhanced to heighten user satisfaction. As in the study of Merkert et al. [26], the more useful drones are, the more competitive they become.

People believe that drone technology can conduct many outdoor missions, military missions, and special missions. The similarity of our findings to those of Nguyen et al. [38] with regard to public safety operations suggests that drone technology can play a significant role in various missions. The current user interface and usefulness levels are not very high. People believe that drone technology is not that risky but they still have some concerns. People know that drone technology can be used for various purposes but they still feel that the UI or usefulness levels are not high. It is important to help people understand that drones are highly useful through practical experience. In addition, we need to improve the UI for better control and utilization of drones. Although we do not feel it is very dangerous, there are still concerns about drone technology so it seems necessary to promote it in order to address these concerns as well as to increase people's experience and utilization of drones.

We were able to develop a questionnaire for drone technology to ask about user preferences in the perception, design, and operation of drones. The questionnaire consisted of two parts. The first part asks about the extent to which the participants have experienced drone technology. The second part contains questions about drone design and operation. The questionnaire can provide a drone design and operation checklist for drone designers and manufacturers. The current study investigated what potential users expect with regard to drone design and operation since user-centered guidelines have not been well-established.

A limitation of this research is as follows. It was difficult to derive specific design guidelines and only the overall preference for the operation was investigated. If we had performed an experimental study, we could have established detailed drone design guidelines. Also, we recruited the survey participants from the Korean population, but we did not consider other populations such as the United States, China, etc. If we had performed the survey with other populations, we might have been able to provide different implications. Nevertheless, this research makes several contributions to drone design and operation by identifying the underlying factor structures of drone technology and several important dimensions that influence the popularization and success of drones. The fact that drones will be increasingly used in the future is clear but for now, this study has discovered the areas on which to focus and pay further attention.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: https://docs.google.com/forms/d/1gJ5odAj0slHBFNgjL9olJCJPZcA5QixJKmpnx7QWGRc/edit#responses, accessed on 20 May 2022.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A Drone Survey Questionnaire

Evaluating Preferences for Drone design and operation

Welcome to the drone survey!

The purpose of this survey is to see what you expect with regard to drone design and operation. Drones are flying robots that include unmanned air vehicles (UAVs) that fly thousands of kilometers and small drones that fly in confined spaces. In answering, please consider the following.

Read each statement. Decide how much you agree or disagree or how much you like or dislike and mark the appropriate response.

The survey consists of two parts. The first part is about your demographic information. Part I comprises eight questions. The second part will ask you about what you expect with regard to drone technology. There are 60 questions related to preferences about drone design and operation in Part II.

It takes about 10 min in total to complete the whole survey.

I. Part I

Please fill out every question in the following questionnaire.

1. What is your gender?

☐ Male ☐ Female

2. The year of birth (e.g., 1976): ________________________________

3. What is your highest degree?

☐ High school (undergraduate student)
☐ Bachelor's degree
☐ Master's degree
☐ Doctorate degree
☐ Other ____________________

4. What is your major/area of study? ________________________

Decide how much you agree or disagree or like or dislike and mark the appropriate response.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree

5. I am an early adopter.

1	2	3	4	5	6	7

6. I have heard about drone technology.

1	2	3	4	5	6	7

7. I know how to control a drone.

1	2	3	4	5	6	7

8. I have experienced drone technology.

1	2	3	4	5	6	7

II. Part I

1. Drone technology is safe.

1	2	3	4	5	6	7

2. Drone technology is risky.

1	2	3	4	5	6	7

3. Drone technology is beneficial to my family and me.

1	2	3	4	5	6	7

4. Drone technology is beneficial to society.

1	2	3	4	5	6	7

5. Drone technology is threatening to my family and me.

1	2	3	4	5	6	7

6. Drone technology is threatening to society.

1	2	3	4	5	6	7

7. Drone technology is as safe or safer than other technologies that perform the same task.

1	2	3	4	5	6	7

8. Using drone technology will be compatible with all aspects of my work.

1	2	3	4	5	6	7

9. Using drone technology will fit into my lifestyle.

1	2	3	4	5	6	7

10. Basically, I find drone technology useful.

1	2	3	4	5	6	7

11. I want no drones over my property.

1	2	3	4	5	6	7

12. What bothers me is that there is no way to identify whether the drone is filming.

1	2	3	4	5	6	7

13. What bothers me is that I cannot infer the purpose of use from the appearance of drones.

1	2	3	4	5	6	7

14. I fear injuries from an accident with a drone.

1	2	3	4	5	6	7

15. Drones scare me.

1	2	3	4	5	6	7

16. How much do you like the idea that a drone can be used for military missions?

1 Very much dislike	2	3	4	5	6	7 Very much like

17. How much do you like the idea that a drone can be used for civil missions?

1	2	3	4	5	6	7

18. How much do you like the idea that a drone can be used for planetary exploration?

1	2	3	4	5	6	7

19. How much do you like the idea that a drone can be used for search-and-rescue?

1	2	3	4	5	6	7

20. How much do you like the idea that a drone can be used for mailing and delivery?

1	2	3	4	5	6	7

21. Drones should perform outdoor missions in very challenging environments.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree

22. Drones should perform indoor missions in very challenging environments.

1	2	3	4	5	6	7

23. Drones with various sensors and cameras should perform intelligence missions.

1	2	3	4	5	6	7

24. Drones with various sensors and cameras should perform reconnaissance missions.

1	2	3	4	5	6	7

25. Drones with various sensors and cameras should perform surveillance missions.

1	2	3	4	5	6	7

26. How much do you like the idea that drones equipped with infrared cameras can give images even in darkness?

1 Very much dislike	2	3	4	5	6	7 Very much like

27. How much do you like the idea that drones can provide a rapid overview around the target area without any danger?

1	2	3	4	5	6	7

28. How much do you like the idea that drones can be put into action immediately without any loss of time?

1	2	3	4	5	6	7

29. How much do you like the idea that drones can manage national parks and agricultural lands?

1	2	3	4	5	6	7

30. How much do you like the idea that drones can track wildlife in different areas?

1	2	3	4	5	6	7

31. How much do you like the idea that drones can observe the effects of climate change?

1	2	3	4	5	6	7

32. How much do you like the idea that drones can monitor the biodiversity of different ecosystems?

1	2	3	4	5	6	7

33. How much do you like the idea that drones can be used for the recognition and investigation of natural disasters?

1	2	3	4	5	6	7

34. How much do you like the idea that a drone can be used for environmental protection?

1	2	3	4	5	6	7

35. How much do you like the idea that drones can be used for delivering packages to customers?

1	2	3	4	5	6	7

36. How much do you like the idea that drones can be applied in marine environments?

1	2	3	4	5	6	7

37. How much do you like the idea that drones can be used for studying marine organisms?

1	2	3	4	5	6	7

38. How much do you like the idea that drones can be used for identifying the location of oil spills?

1	2	3	4	5	6	7

39. Anti-drones that are used to take down offensive drones are needed.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree

40. Runway drones that can be used as a runway for another drone are needed.

1	2	3	4	5	6	7

41. Drones that scare birds away from airport runways are needed.

1	2	3	4	5	6	7

42. Window-cleaning drones are needed.

1	2	3	4	5	6	7

43. Solar panel-cleaning drones are needed.

1	2	3	4	5	6	7

44. Hobby drones are needed.

1	2	3	4	5	6	7

45. How much do you like the idea that drones are controlled and navigated using a radio-control system?

1 Very much dislike	2	3	4	5	6	7 Very much like

46. How much do you like the idea that drones are controlled and navigated using a camera installed on the drone?

1	2	3	4	5	6	7

47. How much do you like the idea that drones are controlled and navigated using an autopilot system?

1	2	3	4	5	6	7

48. How much do you like the idea that drones are controlled and navigated using smartphones?

1	2	3	4	5	6	7

49. How much do you like the idea that drones are controlled and navigated using a brain–computer interface (BCI)?

1	2	3	4	5	6	7

50. How much do you like the idea that drones are controlled and navigated using a smart glass?

1	2	3	4	5	6	7

51. I believe that my interaction with a drone will be clear and understandable.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree

52. I believe that it is easy for drone technology to do what I want it to do.

1	2	3	4	5	6	7

53. Overall, I believe that a drone is easy to use.

1	2	3	4	5	6	7

54. If cost is not an issue, I would consider buying drone technology.

1	2	3	4	5	6	7

55. I am really interested in the sort of functions a drone could offer.

1	2	3	4	5	6	7

56. I could see myself utilizing drone technology in 5 years' time.

1	2	3	4	5	6	7

57. I would like to utilize drone technology.

1	2	3	4	5	6	7

58. A drone will increase satisfaction in my daily life.

1	2	3	4	5	6	7

59. A drone will be able to save time that I spend in my daily life.

1	2	3	4	5	6	7

60. A drone will be able to save efforts that I spend in my daily life.

1	2	3	4	5	6	7

Appendix B

Table A1. Mean and standard deviation of ratings for each item (n = 172).

Variables	Mean	SD	Variables	Mean	SD
a1	4.2	1.38	b29	5.7	1.35
a2	5.5	1.63	b30	5.6	1.32
a3	3.3	1.98	b31	5.6	1.51
a4	3.2	2.03	b32	5.5	1.41
b1	3.9	1.41	b33	5.8	1.34
b2	4.3	1.50	b34	5.5	1.55
b3	4.4	1.60	b35	5.1	1.50
b4	5.3	1.31	b36	5.4	1.53
b5	3.1	1.45	b37	5.3	1.56
b6	3.5	1.52	b38	5.5	1.41
b7	4.2	1.38	b39	5.1	1.55
b8	3.9	1.60	b40	4.8	1.36
b9	4.1	1.47	b41	5.2	1.55
b10	5.0	1.36	b42	5.1	1.60
b11	4.1	1.82	b43	5.2	1.52
b12	5.1	1.49	b44	4.8	1.60
b13	4.9	1.57	b45	4.8	1.39
b14	4.5	1.74	b46	5.0	1.43
b15	3.4	1.69	b47	5.0	1.47
b16	5.2	1.68	b48	5.1	1.54
b17	5.2	1.49	b49	4.9	1.47
b18	5.9	1.30	b50	4.7	1.43
b19	6.1	1.34	b51	4.7	1.44
b20	5.4	1.54	b52	4.6	1.43
b21	5.8	1.40	b53	4.4	1.47
b22	4.7	1.78	c1	5.0	1.75

Table A1. *Cont.*

Variables	Mean	SD	Variables	Mean	SD
b23	5.4	1.39	c2	5.0	1.59
b24	5.2	1.51	c3	4.5	1.58
b25	5.0	1.69	c4	4.9	1.54
b26	5.1	1.54	c5	4.5	1.51
b27	5.3	1.45	c6	4.5	1.70
b28	5.3	1.36	c7	4.5	1.61

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