First-Person View Drones and the FPV Pilot User Experience

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Abstract. First-person view (FPV) drones provide an immersive flying experience to pilots and are becoming popular for recreational purposes. In this paper, we study FPV pilots' flight preferences and how they interact with drones. First, we conducted an online survey with 515 pilots. We found that most pilots build their drones, have five drones or more, fly for three years or less, fly one to five hours per week, and prefer acrobatic flight mode. We present pilots' preferences in equipment, background, involvement with social media, competitions, and sponsorship. We also show the results of a second user study in which we interviewed five experienced pilots. We discuss their flight preferences, the correlation between FPV flying and social media presence, and how to improve the FPV user experience. Our results allow the understanding of FPV pilots' culture and how they interact with drones, enabling future work in the field.

Keywords: Drones · Human-drone interaction · Human-robot interaction · User experience

1 Introduction

Often we hear people express their desire to fly; the idea of seeing and exploring the world from the skies has fascinated humans for centuries. The Wright brothers achieved the first successful controlled flight in 1903 [24], and since then, aviation has been evolving and becoming ubiquitous in society. Unmanned aerial vehicles (UAV), also known as drones, are commonly seen in a broad range of applications (e.g., photography during extreme sports, natural disaster response, racing, and agriculture, among others), and their adaption is expected to continue to increase [20]. However, drones are remotely operated by a human on the ground. Generally, they cannot provide an immersive experience, which is an important aspect in the remote operation of robots [1]. Recently, a new type of flying has emerged, which allows users to control their drones as if they were flying onboard the aircraft [21,23]. This immersive type of drone flying is known as First-Person View, or simply FPV flying, and it is emerging as a popular recreational activity (e.g., drone racing).

FPV drones are equipped with a camera connected to a video transmitter which broadcasts the image to a pilot's goggles. This gives pilots a real-time view as if they were sitting on top of the drone, thus creating an immersive experience similar to virtual reality (VR), giving the sensation of free flight. FPV drones are growing in popularity and being used by hobbyists, video creators, and professional drone racers. Although drones broadcasting images in real-time have been studied in applications like search and rescue and disaster relief, there is a lack of research on the community of pilots who fly FPV recreationally [21].

This paper presents the results of two user studies with FPV pilots. First, we conducted an online survey with 515 FPV pilots to understand their user experience when flying FPV drones. Additionally, in this survey, we elicited research questions for further investigation in a follow-up study. We found that most pilots build their drones, have at least five drones, fly for three years or less, fly one to five hours per week, and prefer acrobatic flight mode. We also present pilots' preferences in equipment, background (e.g., gaming experience, previous RC hobbies), their involvement with social media, competitions, and sponsorship. In a follow-up study, we interviewed five experienced pilots to better understand the online survey results. More specifically, we further discussed their flight preferences, the correlation between FPV flying and social media presence, and how to improve the FPV user experience. Our results allow researchers on human-drone interaction (HDI) to understand how FPV pilots interact with drones. Such understanding guides further development in FPV technologies, and it also serves as a foundation for future research in the field.

2   Related Work

2.1   Human-Drone Interaction

Although some knowledge can be derived from the field of human-robot interaction, the drone's unique characteristic to freely fly in a 3D space and unprecedented shape makes human-drone interaction a research topic of its own [20]. Drones are becoming ubiquitous in our society, and there are unique differences in how users interact with drones compared to other types of robots (e.g., humanoids). Therefore, it is important to understand how humans can interact with them. Current human-drone interaction research has focused on developing natural interaction [4], and new control modalities(gesture [18], speech [12], brain-computer interfaces [14,22], and multi-modal interfaces [8]). Additionally, researchers are enhancing human-drone communication by adding new channels of information, such as using LEDs to communicate directionality [19], and drone's movement to acknowledge system attention [9]. Further examples of research in the field are evaluation of interaction distances [5], social drones [3], and the use of drones for somaesthetics [11]. Even though there is literature on human-drone interaction, such work targets drones in general and lacks focus in FPV drones. One work explored the learning experience of becoming a FPV pilot [23]. The authors found that most pilots (89%) recommend using flight simulators to learn FPV. Most (59%) learned how to fly in angle mode before switching to acrobatic, and those new pilots should seek help FPV community when starting.
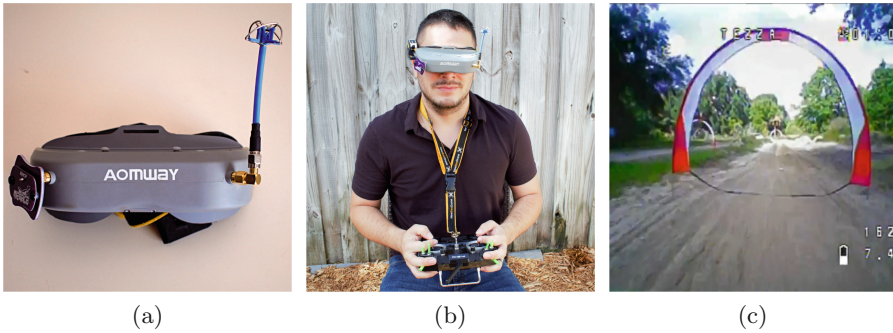
Fig. 1. (a) FPV goggles, (b) FPV pilot, and (c) image displayed on goggles.

2.2 The FPV Drone Racing Sport

Drone racing began in the year 2014 in Australia [25]. As racers shared videos of the races via social media, people worldwide quickly became interested, which led to the Entertainment and Sports Programming Network (ESPN) beginning to televise these events in 2016. Since then, ESPN has continued to provide coverage of the now professional sport [16]. However, drone racing is still young, and research into the topic is lacking [2]. Previous work investigated 18 crashes from the 2016 racing season through analysis of 514 min of video footage to determine what caused them [2]. Furthermore, the Augmented FPV Drone Racing System described in [17] proposes several ways in which the drone racing spectator experience can be enhanced. In addition to allowing spectators to view the race using a FPV headset, as mentioned in [2], this system also puts forward an LED persistence of vision (POV) display attached to each drone, autonomous commentaries, and a motion capture and projection mapping scheme.

3 FPV Flying

First-Person View (FPV) flying differs from traditional line-of-sight (LOS) flying, in which the pilot controls the drone from a third-person view. FPV creates an immersive experience as if the pilot was on board the aircraft by sending commands through a remote controller and receiving visual feedback from the camera on the goggles, as seen in Fig. 1.

While non-FPV drones are commonly equipped with sensors to allow higher levels of navigation and automation (e.g., GPS, compass), FPV drones are equipped with bare-bone hardware consisting of a propulsion system, camera, and power supply [2]. These drones usually have a high thrust-to-weight ratio, making them very agile and capable of reaching over 100 mph. Nonetheless, they are also equipped with frames strong enough to endure crashes. Examples of FPV drones for indoor and outdoor uses can be seen in Fig. 2. Similarly, flight controller software used for FPV flying such as Betaflight and FlightOne focus on

Fig. 2. Two types of FPV drones: 5-in. outdoors drone (left), and 65 mm designed for indoor use (right).

cutting-edge flight performance [6] and usually do not have advanced navigation features such as autonomous flying.

3.1 FPV Remote Controllers and Flight Modes

The remote controller (RC) provides the control interaction between the pilot and the drone. Two factors influence how FPV pilots interact with the RC itself: the form of grip and RC mode. There are three primary forms of grips in which the pilot holds the controller, which are displayed in Fig. 3. Additionally, according to [21] there are four RC modes that dictate how the RC gimbal sticks are translated to drone commands, and two main flight modes commonly used by FPV pilots: angle and acrobatic.

3.2 FPV Racing and Freestyle

FPV flying can be divided into two categories: racing and freestyle. Drone racing is an emerging and competitive sport in which pilots fly FPV drones in complex 3D courses against each other, aiming to be the fastest pilot on the track [2]. Drone racing is significantly more complex than flying non-FPV drones as it requires long practice periods and a high level of skills [15]. Freestyle flying is a broader concept, as there are no specific rules or competitions for this category. There is no previous formal definition of freestyle flying; therefore, we derive its
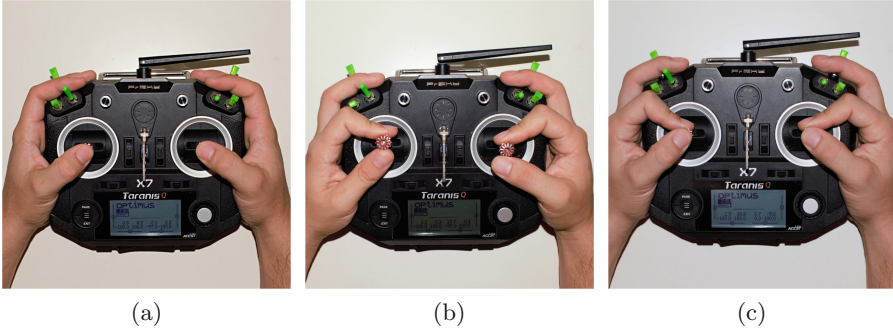
Fig. 3. Types of remote controller grip: (a) Thumb, (b) Pinch, and (c) Hybrid.

definition from another extreme activity, freestyle BMX; where its competitors spend their time performing tricks and stunts rather than racing [13]. Similarly, we define freestyle flying as the category where pilots fly FPV drones to explore spaces and perform tricks and stunts.

4   Study 1 - Surveying FPV Drone Pilots

4.1   Study Design and Procedure

Our first study consisted of a 51-question survey administered via Qualtrics for four months. Questions were related to pilots' backgrounds (e.g., gaming experience, previous hobbies) and how they impact their current flight preferences, previous hobbies and gaming experience, age, and how long they have been flying. Furthermore, we surveyed pilots' flight preferences (flight modes, remote controller grips, and flight simulators), flight controller software, and hardware (batteries, frames, propellers, goggles, remote controllers) preferences. A link to the survey was posted on FPV related groups on Facebook, Twitch, Discord, Twitter, and Reddit. Before completing the survey, participants had to sign an informed consent form digitally.

4.2   Participants

A total of 515 FPV pilots completed the survey. Of these, 505 (98.06%) participants were male, 5 (0.97%) were female, and 5 (0.97%) did not identify as neither male nor female. Additionally, 79 (15.34%) were 18 to 24 years old, 133 (25.83%) were 25 to 34, 176 (34.17%) were 35 to 44, 87 (16.89%) were 45 to 54, 34 (6.60%) were 55 to 64, and 6 (1.17%) were at least 65 years old.

4.3   FPV Pilot Flying Preferences

Flying Categories, Flight Modes, and Remote Controllers. Our analysis of the 515 FPV pilots shows that 43.08% of them fly freestyle only, 8.33% fly

Table 1. Pilots' flight preferences broken down by categories.

	All participants	Freestyle pilots	Racing pilots
Flight mode			
Angle	6.10%	8.02%	14.63%
Acrobatic	92.07%	90.09%	82.93%
Unknown	0.41%	0.47%	0.00%
Other	1.42%	1.41%	2.44%
Controller grip			
Thumb	53.46%	52.36%	51.22%
Pinch	20.9.%	21.70%	19.51%
Hybrid	24.80%	25.47%	29.27%
Unknown	0.81%	0.47%	0.00%
Controller mode			
Mode 1	6.10%	6.13%	12.20%
Mode 2	87.40%	88.21%	80.49%
Mode 3	0.81%	0.47%	0.00%
Mode 4	1.02%	0.47%	0.00%
Unknown	4.67%	4.72%	7.32%

only for racing purposes, and 48.57% fly both racing and freestyle. Table 1 breaks down the flight preferences among these groups. Over 90% of the pilots surveyed selected acro as their main flight mode, suggesting that this is the best-suited flight mode for these flight modalities. To understand the reason why this flight mode is the favorite among FPV pilots, we further evaluate this topic in the second study (see Sect. 5). Furthermore, we looked into whether gamers and pilots with previous RC hobbies preferred racing or freestyle flying; we found no significant differences in their inclinations.

The grip can influence the pilot's interaction with the drone in terms of control latency, accuracy, and comfort. Data in Table 1 shows the majority of pilots (53.46%) prefer to hold their controllers using the "thumb grip", followed by hybrid (24.80%) and pinch (20.9%). Additionally, our results show that controller mode 2 is the preferred RC mode for most pilots (87.40%). The form of grip is another topic that we investigated in the follow-up interviews, and results are presented and further discussed in Sect. 5.

Equipment Preferences. As seen in Table 2, it is common for pilots to own multiple drones, with the majority of pilots owning at least five drones. Results also demonstrate that most FPV pilots build their drones as 481 (93.4%) participants stated they had built at least one drone before. Additionally, Table 3 displays equipment preferences for each flying categories (freestyle vs racing). Results demonstrate that 4-cell batteries and 5 to 5.9-in. propellers are the most

**Table 2.** Number of drones owned by pilots, broken down by flying categories.

Number of drones	All participants	Freestyle pilots	Racing pilots
1	2.85%	2.83%	4.88%
2	8.94%	10.38%	7.32%
3	13.21%	16.51%	14.66%
4	12.20%	14.15%	7.32%
5 or more	62.80%	56.13%	65.85%

Table 3. Equipment preferences broken down by pilot categories.

	All participants	Freestyle pilots	Racing pilots
Flight controller			
BetaFlight	68.03%	67.74%	80.85%
CleanFlight	5.45%	4.66%	2.13%
Kiss	5.76%	6.09%	4.26%
FlightOne	5.78%	3.94%	6.39%
Other	14.56%	16.85%	6.39%
Unknown	0.45%	0.72%	0.00%
Battery size			
1 Cell	12.64%	12.54%	9.26%
2 Cell	8.18%	7.52%	3.70%
3 Cell	12.89%	12.85%	7.41%
4 Cell	51.55%	55.17%	55.56%
5 Cell	5.08%	6.27%	0.00%
6 Cell	9.67%	5.64%	24.07%
Propeller size			
< 2 in.	14.64%	14.10%	10.91%
2.0 to 2.9 in.	11.28%	10.11%	9.09%
3 to 3.9 in.	11.50%	11.44%	7.27%
4 to 4.9 in.	6.07%	5.32%	1.82%
5 to 5.9 in.	45.34%	44.95%	67.27%
6 to 6.9 in.	6.62%	8.78%	0.00%
>= 7 in.	4.56%	5.32%	3.64%
Frame type			
H	4.88%	5.66%	2.44%
X	54.07%	59.43%	46.34%
Stretch X	26.83%	16.98%	46.34%
Wide X	6.10%	9.43%	0.00%
Other	4.27%	2.83%	2.44%
Unknow	3.86%	5.66%	2.44%

used among pilots. This combination is common among racers because it falls under the requirements to compete in racing leagues. Additionally, a probable
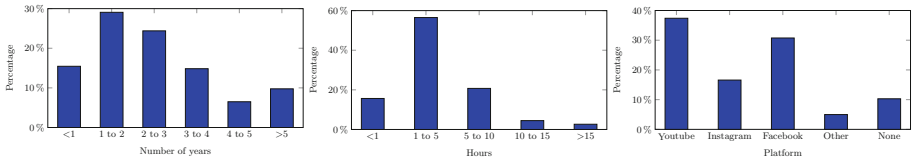
Fig. 4. Number of years each pilot has been flying, hours spent flying per week, and social media preferences.

cause why this is the main choice for freestyle pilots is because it leads to the smallest drone capable of carrying a high-definition action camera (e.g., GoPro) without heavily impacting flight performance. Lastly, we found that Betaflight is vastly the most used flight controller software, which we attribute to its cutting edge flight performance, and for being a free and open-source project with a team of developers actively collaborating with the FPV community.

4.4 Understanding the FPV Community Culture

Pilots' Gaming and RC Hobbies Background. Of the 515 participants, 414 of them reported playing video games regularly. A likely explanation for this high number is the similarity between video games and FPV flying. Players and pilots share comparable remote controllers and watch their activities through a screen. Similarly, 367 out of the 515 participants stated they had at least one other RC hobby before flying multi-rotor drones. Remote-controlled cars were the most common previous hobby (29.17%), followed by fixed-wing aircraft (18.92%), helicopters (14.85%), and boats (7.10%).

Social Media Preferences. FPV flying allows pilots to create and share a new form of audiovisual content on social media platforms. To better understand pilots' social engagement, we evaluated pilots' social media preferences. Our results demonstrate that 89.71% of participants post flight footage on at least one platform. As seen in Fig. 4, YouTube is the favorite platform; however, Facebook and Instagram are also popular among drone pilots. We further explored the correlation between FPV flying and social media presence in the follow-up study, presented in Sect. 5.

Amount of Time Spent Flying. As seen in Fig. 4, the majority of pilots have been flying for somewhere between one and three years. Additionally, less than 10% of pilots have been flying for more than five years. This is expected as FPV drone flying is a relatively new flight modality, only gaining popularity recently, as mentioned in Sect. 2. Moreover, Fig. 4 shows that the majority (56.50%) of pilots spend between 1 and 5 h per week flying.

Competition and Sponsorship. Results show that 80% of racing pilots compete at some level, compared to only 13% of freestyle pilots. Although there are official FPV racing leagues that host competitions, no such leagues exist for freestyle pilots. This is also a plausible explanation for why most sponsored pilots are racers, as these competitions are often televised and draw sponsorships. Results show that 15% of racing pilots receive some sort of sponsorship while only 3% of freestyle pilots do. As FPV sports continue to grow in popularity, we expect official freestyle competitions and sponsorship to emerge.

Relation to Acrophobia. Out of the 515 participants, 138 (26.8%) of them declared fear of heights before flying FPV drones. However, 29 of the 138 (21%) no longer suffer from such fear, suggesting that FPV flying may be an option for acrophobia treatment. This statement is supported by 20 pilots who stated that FPV flying helped them overcome their fear. When asked how FPV impacted their fear of heights, pilots answered with comments such as "being behind the goggles for several years helped me to cope with a mild fear of heights", "My fear has been greatly reduced from repeated exposure while flying FPV", and "I would get vertigo even on the ground prior to FPV. However, after a year or so of FPV, I noticed the vertigo was gone, and I was able to keep my balance better while I was on ladders or high edges." Combined, the above results suggest that FPV has the potential to treat acrophobia. As FPV flying has similarities to VR systems, this finding is supported by the fact that VR is currently used for such purposes [7,10].

5   Study 2 - Evaluating FPV Pilots User Experience Through Interviews

5.1   Study Design and Procedures

To further understand the online survey results, we conducted interviews with experienced FPV pilots. A researcher remotely interviewed each pilot for approximately 30 min. Prior to each interview, the pilot received the informed consent form and provided verbal consent to participate in this study. Each interview was audio recorded for post-analysis. The interview consisted of the following questions:

– Why do FPV pilots prefer acrobatic flight mode, and what are the advantages of this flight mode when compared to a self-level flight mode (angle)?
– What are the advantages and disadvantages of each remote controller grip (thumbs, pinch, hybrid)?
– What are main factors that explain the strong correlation between FPV flying and social media presence?
– How to improve the user experience for FPV pilots?

5.2   Participants

Five FPV pilots participated in this study. Recruitment was also performed solely online on FPV related groups on Facebook. All five participants were at least 18 years old. Additionally, all participants were experienced FPV pilots who have been flying for at least four years, and all of them stated additional involvement in the FPV community: owner of a FPV store, designer and manufacturer of electronic FPV components, professional racer, owner of a large FPV Youtube channel, and professional video content creator.

5.3   Results and Discussion

Flight Mode. Acrobatic (acro) flight mode is the most common flight mode in both racing and freestyle flying. As seen in Sect. 4, 90% of pilots fly acro as their main flight mode, suggesting that this flight mode is the best suited for FPV drones. All five participants stated that FPV pilots desire freedom of movement during flight, which cannot be achieved in other flight modes. Acro flying provides this freedom because the flight controller computer does not auto-level the drone, leaving complete control of the drone's attitude to the pilot. These characteristics allow pilots to explore spaces creatively, perform fast maneuvers, position the drone in any orientation for freestyle stunts, and create video content that wouldn't be possible with self-leveling flight modes. One of the pilots summarized this characteristic by forming an analogy to a Formula 1 car. He explained that the computer is still there with extremely advanced technologies "under the hood", but ultimately the control is in the pilot's hands. Other pilots' quotes expressing the advantages of acro mode are "provides freedom of movement", "it provides freedom during flights", and "it gives you full control and full benefits from drones".

Participants also discussed that acro flying has a steep learning curve. However, after the pilot understands the flight mode and builds muscle memory on the finger movements, acro flight mode becomes easier to control than others. Pilots also noted that the challenge of learning this flight mode makes the experience fun. Another advantage is that acro flight mode makes the drone behavior more predictable as the flight controller computer does not try to adjust the drone attitude without pilot command. The above acro flying characteristics allow pilots to feel more connected to the drone. Ultimately, this flight mode will enable racers to better maneuver around obstacles on the track and freestylers to perform stunts that would not be possible in other flight modes.

Remote Controller Grip. The majority of pilots (53.46%) prefer to hold their controllers using the "thumb grip" (see Table 1). The grip can directly impact the pilot's interaction with the drone. Therefore, we further investigated this matter in this second study. All participants stated that most beginners to FPV start their journey holding the thumb grip because "it feels like the right thing to do." More specifically, previous interaction with technologies like video-game controllers influenced how they held the FPV remote controller for

the first time. However, 4 out of the 5 pilots switched to a pinch grip as they became more experienced. All 5 stated that a pinch grip provides more precise control, a higher perception of the gimbal sticks, and provides an overall better flight experience. An interesting response was that one pilot stated to suffer from "twitching hands" and that he could not precisely control drones with a thumb grip, however, switching to a pinch grip allowed him to overcome the physical constraint and feel more confident when piloting.

The single participant who still flies using a thumb grip also agreed that pinch provides more control. However, he did not shift to pinching because (1) he could not get used to the ergonomics of the grip, which could be due to his previous video-game experience, and (2) he prefers to have the index finger free to work on other remote controller switches. Another interesting fact raised by 3 of the 5 pilots is that the physical stick-ends of the gimbal play a significant role in the user experience as it directly changes the interface between the pilot, the remote controller, and ultimately the drone. Such responses demonstrate that new pilots are influenced by their experience with previous technologies, in this case how they previously held video game controllers. However, such influences might lead pilots to sub-optimal experiences with FPV drones as 4 out of 5 pilots with at least 4 years of experience switched their control grip to pinch. To enhance the FPV pilots' user experience, we suggest future studies quantitatively evaluate and compare each control grip.

Social Media. In this study, we also investigated the correlation between FPV flying and social media presence found in Sect. 4. First, 3 pilots expressed that flying FPV provides such a good experience that they want to share with family and friends. Pilots stated, "FPV makes me feel like I can fly", "it makes me feel like a fighter pilot", and "it feels like flying a jet". They post on social media to share their memories with others and to document their progress as pilots. They also stated that social media is "part of the new world", and posting on it is the new form of "picture albums". A pilot said, "we post for the same reason as we hang pictures on the wall of our houses, to remember our memories and share with others". This was supported by another pilot who defended that they post "for the same reasons why other communities post their hobbies and lifestyle to social media, it is the modern way of sharing good moments". As FPV flying is based on the visual feedback sent to the pilot's goggles, it is not surprising that pilots would like to share their videos demonstrating the sensation of flight with the community. FPV flying can also be considered a new form of artistic expression, as pilots tend to share their creativity through flight footage on social media.

Additionally, 3 pilots also stated that it is common to post on social media to meet other pilots. For instance, one of them stated "I started posting on social media to join the community of pilots, to be part of a group of individuals who share the same interest." This demonstrates that FPV drones are a technology that can bring people together. They also declared that social media is an excellent medium for seeking help within the community, receiving tips

from more experienced pilots, asking for equipment recommendations, and even buying/sell and trade equipment. Finally, two of the pilots explained that social media allows them to trade drone parts with others, bringing a sense of nostalgia as it reminds them of trading cards as kids.

User Experience Improvement. Participants discussed how to improve the user experience in FPV. The main aspect raised by 3 out of the 5 pilots is the need to decrease the learning curve for beginners. Getting started with FPV can be challenging, which can steer new pilots away to other modalities. Tutorials, guides, and summer camps by different organizations can effectively introduce new users to the FPV community. Recently, FPV companies have been releasing bind-and-fly drones, which are FPV drones that are ready to fly out-of-the-box. Although the results from the online survey show that most pilots build their drones, a bind-and-fly drone might be a good option for a beginner that wants to learn how to fly before learning how to build FPV drones. Additionally, pilots often struggle to find legal and safe places to fly. Participants stated that regulations by the government agencies who regulate drones (e.g., FAA in the USA) are hard to read. Therefore, the user experience can also be enhanced by the demystification of current laws and the development of new ones that allow pilots to find flying fields that are both safe and legal.

Lastly, the user experience can be improved by advancements in software and hardware technologies. For instance, since the flying experience is based on the visual feedback in the pilot's goggles, increasing the FPV image quality can enhance the experience. One pilot explained that higher image quality combined with lower latency on the control link allows the pilot to feel more connected to the drone, increasing the overall user experience. In addition, software advancements such as better control algorithms can provide even higher levels of control. Another example of software advancement brought up during the interview that can help users is an auto-tuning feature for FPV drones. Although some pilots might enjoy tuning their quad-copters, some other pilots, especially beginners, consider tuning stressful.

6   Conclusion

First-Person View (FPV) drones provide a unique flying experience. FPV drones allow pilots to immerse themselves while flying, creating a sensation similar to what is experienced in virtual reality environments. In this paper, we surveyed 515 FPV pilots, aiming to understand the FPV community in-depth. Our results allowed us to evaluate different aspects of FPV flying and interactions between pilots and drones. We presented that the majority of pilots build their drones (93%), have 5 drones or more (62%), have been flying for 3 years or less (69%), and fly between 1 and 5 h per week (56%). We also presented that the majority of FPV pilots prefer acrobatic flight mode (92%), mode 2 remote controller mode (87%), thumbs controller grip (53%), and Betaflight flight controller software

(68%). We also discussed pilots' backgrounds and how they affect their experiences and their involvement with social media platforms, official competitions, and sponsorship.

To further understand the results from the first study, we conducted a follow-up study. We interviewed 5 experienced pilots to discuss some of the patterns found during the first study. More specifically, we confirmed that acrobatic flight mode provides the most advantages for FPV flying, discussed the benefits of different controller grips, the correlation between FPV and social media presence, and how to improve the FPV user experience. In conclusion, combining the results of these two studies, we provided an in-depth analysis of the FPV community and the pilot user experience.

References

1. Adalgeirsson, S.O., Breazeal, C.: Mebot: a robotic platform for socially embodied presence. In: Proceedings of the 5th ACM/IEEE International Conference on Human-Robot Interaction, pp. 15–22. IEEE Press (2010)
2. Barin, A., Dolgov, I., Toups, Z.O.: Understanding dangerous play: a grounded theory analysis of high-performance drone racing crashes. In: Proceedings of the Annual Symposium on Computer-Human Interaction in Play, pp. 485–496. ACM (2017)
3. Baytas, M.A., Çay, D., Zhang, Y., Obaid, M., Yantaç, A.E., Fjeld, M.: The design of social drones: a review of studies on autonomous flyers in inhabited environments. In: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, pp. 1–13 (2019)
4. Cauchard, J.R., E, J.L., Zhai, K.Y., Landay, J.A.: Drone & me: an exploration into natural human-drone interaction. In: Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing, New York, NY, USA, pp. 361–365. Association for Computing Machinery (2015). https://doi.org/10.1145/2750858.2805823
5. Duncan, B.A., Murphy, R.R.: Comfortable approach distance with small unmanned aerial vehicles. In: 2013 IEEE RO-MAN, pp. 786–792. IEEE (2013)
6. Ebeid, E., Skriver, M., Terkildsen, K.H., Jensen, K., Schultz, U.P.: A survey of open-source UAV flight controllers and flight simulators. Microprocess. Microsyst. **61**, 11–20 (2018)
7. Emmelkamp, P.M., Bruynzeel, M., Drost, L., van der Mast, C.A.G.: Virtual reality treatment in acrophobia: a comparison with exposure in vivo. CyberPsychol. Behav. **4**(3), 335–339 (2001)
8. Fernandez, R.A.S., Sanchez-Lopez, J.L., Sampedro, C., Bavle, H., Molina, M., Campoy, P.: Natural user interfaces for human-drone multi-modal interaction. In: 2016 International Conference on Unmanned Aircraft Systems (ICUAS), pp. 1013–1022. IEEE (2016)
9. Jensen, W., Hansen, S., Knoche, H.: Knowing you, seeing me: investigating user preferences in drone-human acknowledgement. In: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, p. 365. ACM (2018)
10. Krijn, M., Emmelkamp, P.M., Biemond, R., de Ligny, C.D.W., Schuemie, M.J., van der Mast, C.A.: Treatment of acrophobia in virtual reality: the role of immersion and presence. Behav. Res. Therapy **42**(2), 229–239 (2004)

11. La Delfa, J., Baytas, M.A., Patibanda, R., Ngari, H., Khot, R.A., Mueller, F.: Drone chi: somaesthetic human-drone interaction. In: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, pp. 1–13 (2020)
12. Miyoshi, K., Konomura, R., Hori, K.: Entertainment multi-rotor robot that realises direct and multimodal interaction. In: Proceedings of the 28th International BCS Human Computer Interaction Conference on HCI 2014-Sand, Sea and Sky-Holiday HCI, pp. 218–221. BCS (2014)
13. Nelson, W.G.J.: Reading cycles: the culture of BMX freestyle. Ph.D. thesis, McGill University (2006)
14. Nourmohammadi, A., Jafari, M., Zander, T.O.: A survey on unmanned aerial vehicle remote control using brain-computer interface. IEEE Trans. Hum.-Mach. Syst. **48**(4), 337–348 (2018)
15. Ribeiro, R., Ramos, J., Safadinho, D., de Jesus Pereira, A.M.: UAV for everyone: an intuitive control alternative for drone racing competitions. In: 2018 2nd International Conference on Technology and Innovation in Sports, Health and Wellbeing (TISHW), pp. 1–8. IEEE (2018)
16. Rovell, D.: Drone racing league, ESPN reach broadcasting agreement, September 2016. https://www.espn.com/moresports/story/_/id/17544727
17. Sueda, K., Kitada, T., Suzuki, Y., Wada, T.: Research and development of augmented FPV drone racing system. In: SIGGRAPH Asia 2018 Posters, p. 9. ACM (2018)
18. Sun, T., Nie, S., Yeung, D.Y., Shen, S.: Gesture-based piloting of an aerial robot using monocular vision. In: 2017 IEEE International Conference on Robotics and Automation (ICRA), pp. 5913–5920. IEEE (2017)
19. Szafir, D., Mutlu, B., Fong, T.: Communicating directionality in flying robots. In: 2015 10th ACM/IEEE International Conference on Human-Robot Interaction (HRI), pp. 19–26. IEEE (2015)
20. Tezza, D., Andujar, M.: The state-of-the-art of human-drone interaction: a survey. IEEE Access **7**, 167438–167454 (2019)
21. Tezza, D., Caprio, D., Laesker, D., Andujar, M.: Let's fly! an analysis of flying FPV drones through an online survey. In: iHDI@ CHI (2020)
22. Tezza, D., Garcia, S., Hossain, T., Andujar, M.: Brain eRacing: an exploratory study on virtual brain-controlled drones. In: Chen, J.Y.C., Fragomeni, G. (eds.) HCII 2019. LNCS, vol. 11575, pp. 150–162. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-21565-1_10
23. Tezza, D., Laesker, D., Andujar, M.: The learning experience of becoming a FPV drone pilot. In: Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction, pp. 239–241 (2021)
24. Wright, O., et al.: How we made the first flight. Department of Transportation, Federal Aviation Administration, Office of . . . (1977)
25. Young, J.: Everything you need to know about drone racing, October 2018. http://www.droneguru.net/everything-you-need-to-know-about-drone-racing/