Running with a Drone for Pace Setting, Video Self-Reflection, and Beyond: An Experiential Study

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ABSTRACT

This paper explores the potential of drones in supporting running activities as pacesetters and video recorders. Using questionnaires and interviews, insights were gathered from 10 recreational runners regarding their experience running with a drone in the study and viewing drone-captured videos of their run. Results indicated that participants found the drone experience engaging and minimally disruptive, despite perceiving it somewhat unnatural and having polarized view on the spatial immersion. Analysis of responses unveiled factors affecting runners' experiences, while their reflections on drone-captured run videos revealed benefits of leveraging such footage for post-run self-reflections and opportunities for improvement. Additionally, participants' insights led to the identification of more roles and functions for drones in supporting various running activities, beyond pace-setting and video recorders. This study lays the groundwork for future research, positioning drone utilization in running as a promising avenue for exploration.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; **Empirical studies in HCI**.

KEYWORDS

Drone, Running, Runner Drone Interaction, Pacing, Post-Run Reflections, User Study, Experience Evaluation

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1 INTRODUCTION

With drones becoming more readily available and the integration of cameras becoming a standard feature, the field of human drone interaction (HDI) as such has showcased the diverse capabilities of drones in supporting athletes [18]. By leveraging their flight capabilities and video recording functionalities, drones have the potential to accompany athletes, fulfilling a wide range of needs during and after their activities. For instance Delfa et al. [13] and Zwaan and Barakova [64] have demonstrated the use of drone movements to support activities such as Tai Chi and boxing. Additionally, drone video recordings have proven valuable in sports scenarios like soccer [19, 21, 47], rowing [35], skiing [41], cycling [62], climbing [43], and hiking [27], enabling athletes to reflect on their performances using the video recordings. Similarly, in the context of running, several studies have investigated the potential benefits of using drones and drone videos to support and enhance the running experience (most notably [17, 19, 34, 44]).

Graether and Mueller [17] and Mueller and Muirhead [34] demonstrate the utilization of drones in the running domain and show how their movements can be harnessed to support runners, offering recommendations for the design of interactions for drones that accompany runners based on users' experiences running with a drone. Mueller and Muirhead [34], in particular, elaborate on what functions the runners desired. One such function was for the drone to act as a pacesetter, which was also identified through the work of Seuter et al. [49] via an online survey of self-identified runners. We build on this and, as the first objective of our study, look more elaborately at the runners' experience quantitatively and qualitatively while using drones as pacesetters. By identifying crucial aspects of this experience, we can shed light on the factors that impact the overall running experience and help researchers leverage the beneficial aspects to enhance the runners' experience with the drone as a pacesetter.

Higuchi et al. [19] and Romanowski et al. [44] carried out studies investigating the use of aerial videos in the running domain. They have demonstrated the use of aerial videos to facilitate third person perspective visualization of runners to the runners themselves [19] and to generate support from spectators in marathon settings [44]. However, apart from these identified opportunities, there is a lack of research specifically exploring runners' preferences on how they would like to utilize drone videos of themselves for post-hoc self-reflection. To address this, the second objective of our study was to assess runners' insights after viewing the drone videos recorded while they were running with a drone. We aim to uncover the benefits of using drone videos and identify ways to enhance their presentation and utilization, enabling runners to engage in meaningful post-hoc self-reflection on their runs.

Furthermore, the third objective of our study was to identify additional roles and functions that drones could support during running, through an analysis of runners' reflections. This exploration went beyond the roles of a pace setter or video recording device and was informed by the runners' first-hand experiences running with a drone. Through this, we show a wider range of running situations off-the-shelf drones could be used to enhance the running activity.

To fulfil our objectives, we designed a study where 10 runners were instructed to run on an outdoor track while being accompanied by a drone positioned on their side. We used a commercial drone capable of autonomous flight and video recording. The drone was programmed to maintain a ground speed of 10km/h, as a pace setter, and record the runners' run, to facilitate post-hoc video self-reflection. Participants were instructed to synchronize their pace with the drone's position on the side and complete two rounds on the track. After the run, participants were asked to complete the ITC-SOPI questionnaire [28] and undergo interviews to assess their experience. They then watched the recorded drone footage of their run and participated in an interview to gather insights on the use of drone videos for post-run self-reflections. The interviews furthermore invited the participants to more widely reflect on possible roles and functions of the drone. By providing runners with the opportunity to run with a drone, outdoors, our aim was to recreate the sensations, emotions, and feelings they might encounter during an actual run, thereby eliciting insightful reflections that we can subsequently evaluate.

By conducting our study, we discovered meaningful insights and make the following contributions to this field. The runners' responses to the ITC-SOPI questionnaire highlighted the engaging nature of running with a drone and its minimal disruptive impacts on the running experience. However, participants expressed that the drone experience lacked a sense of naturalness and the level of immersion was unclear. Through analyzing their interview responses, we identified some factors that may have influenced their perceptions. This included: Drone Presence, Position, Speed, Noise, and Length of Experience. Furthermore, participants' reflections on the drone-captured videos revealed the benefits of incorporating drone footage for post-run self-reflections. Their feedback provided valuable insights into refining the presentation and utilization of drone videos to better support post-run self-reflections. Additionally, based on in-depth analysis of the interview data, we derived various roles and functions for drones in enhancing the running experience, such as AirTrainers, Companions, Trail/Forest Drones, Alerter & Navigators, Social Media Facilitators, Riveting, Exergame Conductors, Behavioural Catalysts, and Sightseeing Coaches. These findings, substantiated by user feedback, not only demonstrate the potential of drones in supporting runners but also inform future research and development efforts to optimize the use of drones and drone videos in pacing activities and post-run self-reflections.

Our contributions aim to guide future work by leveraging the positive outcomes and addressing the challenges associated with utilizing drones to support pacing activities. With the work in this paper, we seek to facilitate the future development of optimized pacing experiences that effectively address the drawbacks identified by runners. Additionally, we aim to raise awareness among researchers and practitioners about the value of drone videos in supporting post-run reflections. By identifying the benefits and offering insights on how to enhance their utilization, we provide valuable background information to support their future endeavors. Furthermore, our identification of specific roles and functions opens up avenues for further investigation and the development of accompanying systems to better support and assist runners.

2 RELATED WORK

Our work is related to 1) technology driven pace training experiences in running, 2) supporting post activity self-reflections using video recordings, and 3) deriving roles & functions for drones to support running activities

2.1 Technology Driven Pace Training Experiences in Running

Effective pacing strategies and pace training offer significant benefits for runners. By adopting a well-defined pacing strategy, runners can maintain optimal energy levels, enhance endurance, and improve overall running performance [9, 29, 39, 42]. Previous studies have consistently highlighted the advantages of pacing techniques, emphasizing the importance of deliberate practice in this area [2, 56]. Developing pacing abilities would enable runners to manage their effort, maintain a consistent pace, and make informed speed adjustments, resulting in more efficient and successful performances [2, 11, 56].

There are several existing technologies that support pace training or enable runners to maintain a specific pace, as noted in our earlier extensive literature review [3]. Treadmills, for instance, are designed to help runners train at varying and precise paces [46, 48]. However, they fall short for outdoor runners who prefer the challenge of diverse terrains. In outdoor settings, runners typically rely on smartwatches or smartphones (or similar technology) to monitor their pace during or after a run [23]. While post-run pace analysis provides valuable information, real-time access to pace during the run can be more engaging and motivating. Yet, constantly checking pace throughout the run could disrupt the flow and hinder performance [50]. To overcome this, an external visual cue within the running environment could reduce cognitive load compared to secondary actions like glancing at a smart devices or relying on vibrations. Visual systems such as a cyclist maintaining a fixed pace, a car equipped with a laser pointer (as seen in Kipchoge's marathon race [4]), light based systems like WaveLight [54], or even robots could provide such cues [34, 40]. However, systems involving cyclists or cars require additional personnel and may not be logistically feasible for solo training. Light based systems like WaveLight [54], which utilize ground-based lights in specific stadium locations, limit runners to those particular areas. Alternatively, ground robots like the Puma BeatBot [40] could be used, as they can follow any designated line. Yet, they have limitations tied to level ground requirements and the need for a predetermined path. Considering these limitations, drones offer a compelling solution. As flying robots, drones can be programmed at different speeds and are not constrained by terrain limitations. While previous research, such as the notable work conducted by Mueller and Muirhead [34], has demonstrated the feasibility of using flying robots as pacers and has provided valuable insights into their design considerations, our primary focus in this study is to utilize this knowledge to assess the experiences of runners who run with a drone as a pacesetter. As a pacesetter, we employ a drone to direct and guide the runners while supporting them in maintaining a steady pace throughout their runs. Through the drone we offer a continuous visual cue to the runners, reminding them of the pace they should maintain.

2.2 Supporting Post Activity Self-Reflections using Video Recordings

Self-reflection empowers athletes to draw upon their prior experiences, effectively leveraging them to improve future performances in pursuit of their goals [63]. Previous studies have explored the use of various tools to support self-reflection on running data, including dashboards [38], applications on smartwatches, smartphones, and smart devices [23, 26, 36], physicalization of data [1, 32], and integrated displays on running shoes [60]. While these reflection tools have different objectives, they share the common goal of enhancing self-knowledge, self-modelling, and goal tracking to help with promoting positive running behaviour, motor learning [14, 51], and self-development in sports [22].

Although various forms of running data representation have proven useful for post-run reflections, videos of running activity can offer a more detailed perspective, capturing subtleties of movements that may not be visible through other data representations mentioned above. Videos can help provide a relational and constructive view, aiding in framing and representing movement more accurately than simplified data which may not help capture the complexity of running motion. Research conducted in various sports have demonstrated this and also demonstrated the beneficial effects of self-reflection through videos showing positive impacts on physical performance, skill acquisition, and motor learning [10, 37, 61] while also assisting athletes in effectively articulating their thought processes during sporting activities [45]. While previous studies have demonstrated the potential of video, particularly drone videos, in other sports [19, 21, 27, 35, 41, 43, 47, 62], there is limited research exploring the use of drone videos specifically for running. Higuchi et al. [19] have presented how aerial videos could help runners visualize themselves in third person perspective, to improve their performance and supporting training. Romanowski et al. [44] have shown how drone videos can enhance the experience of marathon runners. Although few studies have contributed to our understanding of how aerial videos can be utilized for post-run running reflections, their potential remains largely unexplored. In contrast to these earlier works, our study aims to understand runners' perspectives on the benefits of viewing their drone video of running with the drone as a pacesetter and how drone videos can be presented/utilized to facilitate meaningful post-run reflections.

2.3 Deriving Roles & Functions for Drone to Support Running Activities

In the context of running, studies by Mayer et al. [31], Romanowski et al. [44], Seuter et al. [49], and Mueller and Muirhead [34] have identified various roles and functions that drones could fulfill to support runners. However, the recommendations of Mayer et al. [31] and Romanowski et al. [44] are based on their experiences working with drones rather than on an analysis of runners' preferences. Seuter et al. [49], on the other hand, considered user preferences through an online survey to understand how self-identified runners would like to incorporate drones in their running activities. Although these studies have identified valuable roles and functions for drones, we believe that one limitation in these works was the absence of runners running with the drone to form their opinions. As interpreted in the work of Cronin et al. [12] having lived an experience helps better understand the phenomenon of a technology, in our case the drone. By allowing runners to run with drones, they would have the opportunity to interpret the technology and provide more meaningful insights by considering their sensations, emotions, and feelings experienced during the run. Mueller and Muirhead [34]'s study adopted this approach, enabling runners to gain a deeper understanding of how drones could be better utilized to support their running activities. However, given the growing accessibility of running technologies that enhance self-understanding and self-realization within the running lifestyle [53], we believe there are undiscovered functionalities for drones to support runners beyond those identified by Mueller and Muirhead [34]. Therefore, in addition to acting as pace-setters and video recording devices, our analysis of runner responses aims to identify further desired roles and their functions substantiated by their experiential knowledge of running with drones. Furthermore, earlier works in the field of Human-Drone Interaction (HDI) have shown that people associate both utilitarian and hedonic values with drones and attribute specific roles and functions to drones depending on the situation [25]. However, Herdel et al. [18] have pointed out that interaction techniques in HDI are often developed and evaluated without providing users with the necessary context regarding the intended roles and functions of the drone. This contextual information is crucial for obtaining aligned feedback and enhancing study validity. Additionally, the lack of context may affect users' responses, as they are not provided with sufficient information to allow for appropriate feedback. Therefore, by identifying additional roles and functions, we aim to support future researchers in aligning their work.

3 STUDY

To gain insights into the runners' experience of running with a drone as a pacesetter, understand how the drone footage of their run could be used to better support post-run self-reflections, and uncover additional roles and functions for drones we conducted the following study. In the following subsections we describe our participant pool, the design of the study, the procedure we followed and measurements we took, and finally the procedure we followed to analyse the collected data.

3.1 Participant Pool

We recruited 10 experienced runners (4 female, 6 male) aged between 22–60 years (mean = 30.6; median = 26; std. dev. = 11.5). The participants had varying years of running experience (1-14 years, mean = 5.9 years), and ran outdoors 2-4 times every week covering an average distance between 15-60 km (mean = 21.9; median = 17; std. dev. = 13.6). Most of them run outdoors by themselves. The participants were recruited through local channels and flyers posted around the university and were compensated for their time

Figure 1: DJI Mavic Pro 2 Setup used for the Study

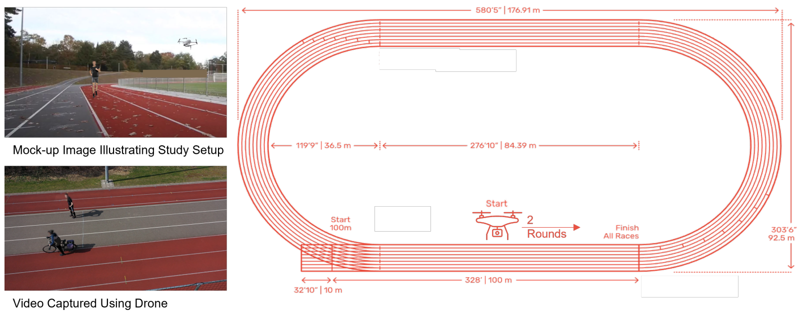

Figure 2: Dimensions of Running Track Used for the Study and Images Illustrating the Study Setup and Video Captured

through treats. Before this study, the runners had never used or operated a drone.

3.2 Study Design

The study took place outdoors, at the university's athletics track, in order to replicate a training environment that closely resembles real-life conditions for the runner. A DJI Mavic Pro 2 drone fitted with propellor guards (Figure 1) was used in this study. Litchi, a drone flight planner was used to program the drone to fly automatically along the inner perimeter of the track at a constant ground speed of 10km/h for two laps. In case of an emergency, the pilot was ready to take over the drone control to prevent any damage. The drone's airspeed was calculated using track dimensions (Figure 2) to maintain a constant ground speed during both straight sections and curves. To ensure consistency and minimize variables in analyzing participants' running patterns using videos for future studies, we maintained a constant drone speed throughout the study. The drone was carefully positioned near the runner, considering safety, video capture requirements, and environmental constraints. Ample distance was maintained between the runner and the drone throughout the study to ensure safety and allow the pilot to respond in emergencies. The drone's position was optimized to capture the runner's sagittal plane view, even in cases of deviation from the prescribed path. To address the soccer pitch in the center of the athletics track, a 6.5m net was installed along the inner perimeter to prevent ball exit. To account for all of these requirements and for a safe and compliant drone flight, the drone was placed 7m high and 7m horizontally on the left side of the runner. Additionally, a cyclist accompanied the runner to ensure clear paths and safety for all individuals involved. Given the participants' running experience, we refrained from conducting specific health checks, instead relying on their self-assessment of their fitness to run prior to the activity. The study was reviewed by the ethics board at the university, and the drone pilot followed all the necessary rules and regulations as specified by federal law. The study also took the necessary precautions to also uphold the safety of the people not involved in the study.

3.3 Procedure and Measurements

Before the start of the study the runners were asked to sign a consent form, and were briefed about the study's objectives. The runners were made aware of the safety procedures in place, and were given the option to stop the study at any time. The runners were instructed to maintain their pace using the drone's position and were asked to stay as center as possible when following the drone on their left. They were also instructed to run in the last lane of the track to ensure the video of their run is captured clearly. At the end of the run, we interviewed the runners and asked them to fill out a modified version of the ITC-SOPI questionnaire [28] to evaluate their experience. To avoid recall bias the interview was conducted immediately after the run. This was also the reason for keeping the study relatively short. To avoid expectancy bias, the interviewer maintained a neutral expression and refrained from employing suggestive or leading language.

The primary aim of the first interview was twofold: firstly, to fulfill our first objective of understanding runners' experience running alongside drones as a pacesetter and secondly, to fulfill our third objective of gathering insights into their expectations from drones. The interviews were audio-recorded and semi-structured. The first part of the interview included questions about their experience running with a drone: "What was it like to run with a quadcopter?", "Did the quadcopter effect your regular running experience if so how?", "How did you feel when the quadcopter effected your regular running experience?", "What more can this technology do to help you with the running experience?". After the runners responded to these questions and had enough time for self-reflection, they were asked out to fill out a modified version of the ITC-SOPI questionnaire.

The ITC-SOPI questionnaire is used to assess users' presence-related experiences in a displayed environment. It evaluates four dimensions of an experience: Spatial Presence, Engagement, Naturalness, and Negative Effects. While originally designed for virtual experiences, we adapted the questionnaire as we recognized the questions could be valuable for evaluating dimensions relevant to the real-world experience we created. Ambiguous terms related to virtual worlds were removed, and irrelevant questions were excluded. The on-field researcher provided assistance to clarify any unclear questions for the runner.

After completing the questionnaire, the runners were presented with a video recording of their run captured by the drone. The video was viewed on a laptop using VLC media player, allowing the runners to control playback speed and pause/play as desired. Subsequently, to fulfill our second objective of the study, the runners were asked specific questions regarding their experience after watching the video and their ability to reflect on their run using the footage. The questions included: "Do you want to change your response about your experience running with a quadcopter after viewing the video of your run if so how?", "Could you comment on how the video helps in perceiving your run and does it help inform you about the way you run and how?", and "Does watching and reflecting about your run in the video, help you correlate the thoughts that may have been running on your mind during the run, if so how?". Additionally, the runners were given the opportunity to share additional feedback or thoughts on the study and their experience.

3.4 Data Analysis

The responses to the ITC-SOPI questionnaire were evaluated following the instructions provided by the authors of the questionnaire through an email request. The audio recordings of the interview were automatically transcribed using Otter.ai and were also manually checked to correct any discrepancies. The interview data was imported into Atlas.ti, and an open-inductive coding approach was used to analyze the responses [6]. Before being archived and stored, the audio and video data collected during the study were anonymized.

We calculated the descriptive statistics (means and standard deviation) of the runners' responses to the ITC-SOPI questionnaire for each dimension. Before computing the statistics, responses to the 5-item Likert scale (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, and Strongly Agree) were converted to values from 1-5. The data obtained was visualized using a box plot as shown in Figure 3. To further analyse the dimensions, we created a stacked bar plot of the responses to questions for each dimension, as shown in Figure 4. To supplement the ITC-SOPI dimension analysis, using affinity diagramming the generated codes were grouped together, with a focus on sentiments. We identified phrases and terms from the data that indicated a positive, neutral, or negative sentiment toward the experience. We discovered that we could associate the grouped codes under each sentiment to a factor related to the experience and also relate them to the dimensions of the ITC-SOPI questionnaire.

In addition, we created a similar affinity diagram based on codes derived from runners' reflections and their perspectives regarding the use of drone videos for reviewing their runs. The coding process aimed to provide a deeper insight into the advantages of utilizing drone footage for post-run self-reflection and to identify ways to enhance the presentation of drone videos to support runners in their self-reflection experiences.

Following the previous rounds of analysis on the interview responses, we conducted a round of thematic analysis with the objective of identifying the roles and functions that runners desired from drones. We chose a reflexive thematic analysis approach due to the exploratory nature of this study [7]. This approach involved coding the data by focusing on the data itself (inductive) and the explicit information provided by the runners (semantic). Through discussions with the second author, who possesses more experience in qualitative data analysis, some of the codes were further clarified and improved and we then identified nine themes from the generated codes. These themes were defined and named to represent the roles and functions that drones could fulfill to meet the runners' needs. In the subsequent sections, we will elaborate on these themes, providing examples of how runners intend to utilize drone technology during their runs and their expectations regarding how drones can support their running activities.

4 RESULTS & ANALYSIS 1: EXPERIENCES OF RUNNERS PACED BY A DRONE

The summary of the calculated statistical values were as follows: Spatial Presence (Mean: 2.7; SD: 1.1); Negative Effects (Mean: 1.5; SD: 0.9); Naturalness (Mean: 2.6; SD: 0.9) and Engagement (Mean: 3.4; SD: 1.1). Examining the spread of results as depicted in the accompanying boxplot (Figure 3), offer noteworthy results. Firstly it becomes apparent that majority of the runners found their experience to be engaging. This is particularly interesting considering the physically demanding nature of the running activity. Secondly, it is noteworthy that a substantial number of runners expressed disagreement with the descriptors associated with the negative effects dimension. Indicating that most runners did not perceive their experience with the drone as having negative implications. However, the dimension of naturalness received scores leaning towards the lower end of the spectrum, implying that many runners did not perceive their experience as entirely natural. Lastly, despite the fact that the interaction took place in the real outdoor environment, opinions on the sense of spatial immersion varied significantly among the runners. This variability could stem from the diverse ways individuals perceive their spatial engagement with technology in a real-world setting, possibly influenced by individual preferences and prior experiences.

In order to gain a more comprehensive understanding of the runners' perspectives, we thoroughly examined their responses to

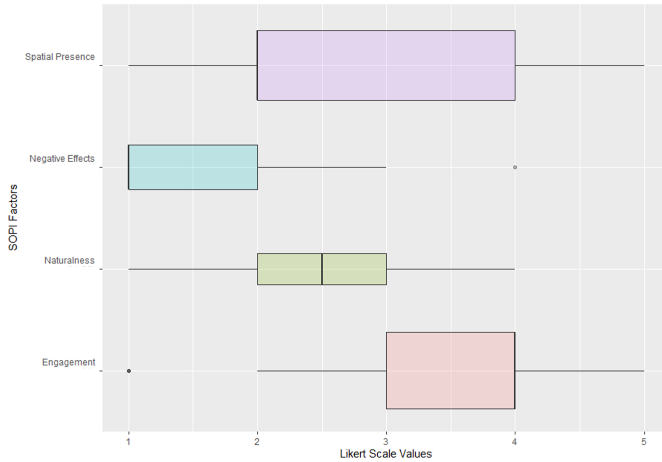

Figure 3: Box Plot Illustrating Responses to the ITC-SOPI Questionnaire, Providing Insights into the Runners' Experience of Running with a Drone.

the interview questions. By utilizing their interview responses as a reference, we further analyzed and interpreted their selections in the ITC-SOPI questionnaire, whenever applicable. As indicated earlier, the questions in each dimension of the ITC-SOPI questionnaire were grouped together and presented as a stacked bar plot, as shown in Figure 4. This approach allowed us to delve deeper into the runners' thoughts and provide a richer interpretation of their experiences and viewpoints.

Spatial Presence: The overall mean score for spatial presence (evaluation of the sense of being physically present at/immersed in the space of the experience) does not fully reflect the runners' opinions on their immersiveness of the experience. However, the bar plot in Figure 4a provides additional information that reveals more about their perspectives. The runners expressed that they did not feel a sense of physical contact with the drone (Q2) or that it provided them with a feeling of being transported to different locations (Q3). This was mainly due to the runners being confined to a specific location and running alongside the drone, which maintained a safe distance. Furthermore, the runners indicated that their movements were reactive to the experience (Q5) and they had limited control over altering the course of the experience (Q9). They also perceived that the drone was not responsive to their actions (Q11). This is evident from the fact that the drone dictated the runners' pace and the experience lacked options for the runners to modify its parameters or have the drone respond to their actions.

The varied responses to the remaining questions do not offer definitive evidence regarding the impact of the drone on the immersiveness of the experience. However, this does not necessarily indicate a negative outcome, as running is an activity that individuals engage in to achieve a state of full immersion, where they can become absorbed in their thoughts, breathing, and personal focus. If the presence of the drone in the physical space did not disrupt this state, it could be considered a positive aspect. Nevertheless, by analyzing the interview responses, we can glean some insights into the factors that positively or negatively influence the spatial immersiveness of running with a drone.

- <u>Drone Presence:</u> Several runners mentioned that after the first round of running, they became accustomed to the presence of the drone, and it had no noticeable impact on their running experience thereafter. They also expressed that the drone did not distract them from estimating their running time. One participant stated, *"I tried to adapt as much as possible, but overall, I would say it's not bothering during the run. So it's a good feeling..."* [P5]. Another runner mentioned, *"In the first lap I had to get accustomed to it but then in the second lap I was just normal routine of running. Get into the rhythm, which I could easily sustain"* [P10].
  The presence of the drone had a positive impact on some runners as it prompted them to reflect on their performance and make adjustments in the moment. They felt more self-conscious due to the perception of being observed. One participant expressed, *"...it has kind of a positive effect because I kind of thought about myself and what I'm doing at the moment and that I don't lose kind of the shape while running... I do not really reflect during running what I'm doing, and this time I really did"* [P5]. Another participant mentioned, *"...it was adding, how to say, changing my way of checking myself..."* [P9]. The feeling of being watched by the drone encouraged these runners to be more mindful of their running form and actions.
- <u>Drone Noise:</u> While the noise generated by the drone was generally perceived negatively by the runners, there were a few exceptions. One runner mentioned that the noise actually had a positive effect as it made them feel more alert and aware of their surroundings. They stated, *"...alerted cause I don't know what's going on. And then I did I knew it was a drone..."* [P10].
  However, for most runners, the noise would be uncomfortable and strange, particularly when they run alone. One participant expressed, *"It may be a bit uncomfortable because mostly I run by myself, alone"* [P5]. Another runner shared concerns about feeling affected and endangered by the noise, especially when running in secluded areas like the woods [P10].

Figure 4: Stacked Bar Plot Illustrating the Responses to Each Factor of the ITC-SOPI Questionnaire (Top Left: Spatial Presence; Top Right: Negative Effects; Bottom Left: Naturalness; Bottom Right: Engagement)

Interestingly, although some runners initially found the noise triggering, they gradually became accustomed to it as the run progressed. As one participant noted, *"In the beginning, you're a little bit triggered but the noise... you're accustomed to, so you don't really hear it... it's not that irritating"* [P10].

- Length of Experience: Some runners expressed that the duration of the study or their experience running with the drone was not sufficient for them to fully adjust to the presence of the drone or accurately assess its impact on their running. One participant mentioned, *"I think the user experience would be a little bit more different if I would have run for like five or six more rounds so that I really get into this running movement pattern"* [P5]. Another participant shared a similar sentiment, stating, *"...maybe I should have run longer... because I think there's also kind of time that we need to adjust each other"* [P9]. These runners believed that a longer duration of running with the drone would have allowed for better adaptation and a clearer understanding of the drone's influence on their running experience.

Negative Effects: The overall mean score for the negative effects (evaluation of the negative reactions of the experience) dimension of the experience indicated that the runners was not negatively impacted by the experience. Upon examining the responses for the questions assessing negative effects (Figure 4b), it is evident that the runners generally did not experience feelings of tiredness (Q2), dizziness (Q3), nausea (Q4), or headaches (Q5) after a short run (less than 5 minutes) with the drone. However, it is worth noting that one runner reported feeling tired, although this occurrence was not documented and could potentially be attributed to their pre-existing physical condition or the environmental conditions, such as sunny weather.

Regarding the sensation of feeling disoriented (Q1), the runners expressed mixed opinions. The reasons for this can be attributed to various factors related to the presence of the drone during the experience, as revealed through qualitative analysis of the interview responses. Excerpts from the interviews provide insights into why these factors in drones may have contributed to the runners' feelings of disorientation.

- Drone Position: The position of the drone during the run was generally perceived as unfavorable by most runners. In order to maintain pace with the drone, runners had to constantly monitor its position, which proved to be distracting and took their focus away from maintaining their running form. One participant expressed, *"...I had to keep the mind on the drone too, it was like, distracting from the pace..."* [P6]. Another participant described the mental challenge of multitasking, stating, *"...looking at the quadcopter I was trying to focus on two things at the same time... which is mentally [exhausting] trying to do two things at the same time"* [P2]. The positioning of the drone required runners to not only locate it for pacing, but also constantly monitor its location relative to their own. As one runner stated, *"I have to take into account of the drone during the running and not really just flying next to me as a pacer but really focusing on where it is and where I am in the view"* [P1]. Additionally, one participant mentioned the difficulty of tracking the drone's position when it happened to be positioned against the sun, obstructing visibility. They stated, *"...the drone was exactly in the sun so I could not really look up and see where the drone was..."* [P7].
  Furthermore, for some runners, the drone proved to be counterproductive to their goal of clearing their mind while running. The need to concentrate on the drone and the surrounding environment became mentally taxing, as expressed by one participant: *"...mostly mentally trying, to do two things at the same time"* [P2].
- Drone Speed: One runner [P9] expressed their concern about the drone's pacing speed and its potential impact on their ability to focus internally during the run. They believed that if the drone's pacing speed is inconsistent, uncontrollable, or fails to adapt to their own speed during the run, it would be an annoying experience. The runner stated that during interval training sessions, their focus is solely on maintaining a constant speed, and any deviations in the drone's pace would be disruptive. They mentioned, *"... for interval training I don't hear I don't listen, I don't feel anything. I'm just trying to pace up myself and then keep that constant speed and in that sense, ... I will be really annoyed if the speed does not adapt"* [P9].
  Additionally, the runner highlighted the annoyance that could arise when they need to slow down or speed up during the run for hydration or other reasons. They stated, *"When you would like to slow down and speed up sometimes...it becomes annoying because [the drone] will...go forward and then not really follow me"* [P9]. The runner also expressed concern that instead of focusing on themselves, they would be preoccupied with catching up to the drone, further illustrating the potential distraction caused by an inconsistent pacing experience, *"...I will not be focusing on myself but focusing on whether or not like I'm catching up with the drone"* [P9].
- Drone Noise: The noise produced by the drone's motors is an inherent characteristic that cannot be completely eliminated. However, the specific characteristics of the noise can vary depending on the type of motors and drone configuration used, resulting in different impacts on the runners.
  For some runners, the noise of the drone proved to be disruptive and disorienting, causing them to lose focus on their running environment and surroundings. One participant expressed that the constant sound of the drone was disturbing and hindered their awareness of what was happening around them. They stated, *"It was a little bit disturbing to hear the sound all the time because I was not really 100% aware of what's going around me"* [P4]. Another participant echoed a similar sentiment, noting that the noise of the drone was also distracting and affected their situational awareness. They stated, *"It was a little bit disturbing to hear the sound all the time because I was not really 100% aware of what's going around me"* [P5].
  These responses indicate that for some runners, the noise produced by the drone had a negative impact on their ability to maintain full awareness of their running environment, potentially affecting their overall running experience.

Naturalness: The overall mean score for the naturalness (evaluation of the reality of the experience) dimension of the experience indicated that the runners did not find the experience highly natural. While the runners acknowledged that running with a drone was believable (Q2) and part of the real world (Q3), they also expressed that the experience did not feel entirely natural (Q1) (Figure 4c). Upon analyzing the interview responses, it became evident that certain factors related to the experience and the drone itself contributed to this perception of unnaturalness.

- Drone Position: Some runners found it unnatural and inconvenient to constantly turn their heads to check on the drone's position during their runs. This movement was perceived as forced and non-natural, potentially affecting their overall running experience. *"Quite hard as it was flying right above me and next to me instead of in front"* [P1], *"... you just have to look up and to the left every time so maybe it was a little bit annoying..."* [P4], *"I think that doing it constantly it will be not good. I have to say because you are like moving muscles in a non-natural way"* [P6], and *"It feels a bit unnatural to look left up during running well, every now and then to see whether you're still on the same line as the drone is"* [P7]. These responses highlight the runners' concerns about the impact of constantly monitoring the drone's position on their body movements and the overall flow of their run.
- Drone Speed: Some runners noticed inconsistencies in the drone's speed, specifically during curves on the track. While the drone's overall speed remained consistent, the adjustments it made to navigate the curves resulted in abrupt changes that were observed by the runners. This phenomenon impacted their running experience. This led to comments such as, *"I found it a bit hard to keep a constant pace"* [P3] and *"it was a little bit annoying or it didn't keep up the pace"* [P4]. Adjusting to the drone's speed proved difficult for some runners; *"… sometimes it was a little little hard because I was a little in front or a little back or so on. So I tried to adapt as much as possible… "* [P5], *"… difficult to maintain the pace … a little bit difficult, especially in the curves"* [P6]. The speed variations became particularly noticeable during the corners; *"The corners... I am moving faster than the drone... I really want to focus on the speed, so I don't want to check whether or not it's pacing me correctly"* [P9] and *"During first corner I really had struggles adapting to the speed of the drone"* [P10]. Additionally, one runner expressed discomfort with the fixed pace set by the drone, stating, *"I don't try to keep a constant pace, but it feels a bit unnatural this way"* [P7].
- Drone Noise: Some runners expressed their dissatisfaction with the noise produced by the drone during the running experience. One participant stated, *"I did not really like the sound"* [P3], while another described it as *"a bit loud"* [P5]. One runner even compared the noise to that of a construction site, saying, *"I feel very annoying with the sound. Yeah, exactly you're in a construction site"* [P8]. Another participant humorously remarked, *"But like after three seconds, it was okay, because I understood it was the drone and not the bees"* [P3].

Engagement: The overall mean score for the engagement (evaluation of the psychological/cognitive involvement in the presented experience) dimension indicated that the runners found the experience engaging. However, a closer look at the individual questions within the engagement dimension provided more insights (Figure 4d). The runners unanimously reported that they paid more attention to the experience than their own thoughts (Q11). Despite the simplicity of the experience and the lack of input from the runners, they still felt involved and engaged during the experience (Q7). They expressed enjoyment in running with the drone (Q9) and were able to recall their experiences well (Q4). Additionally, they indicated that they would recommend this experience to others (Q5). Most runners agreed that they did not have strong emotional responses during the experience (Q12) and that the experience appealed to them (Q13). However, there were variation in the responses to the remaining questions, which was also reflected in the interview responses. These variations could be attributed to different factors related to the experience that triggered specific reactions from the runners, which we further explain below.

- Drone Presence: For some runners, the drone acting as a pacer provided a fun experience that was different from running behind a cyclist/human pacer. One participant expressed, *"I think it was a fun experience. It was different than just behind a cyclist"* [P4]. Another participant creatively imagined themselves as a detective being chased in a movie set, saying, *"I just tried to imagine I'm a detective in a movie"* [P6], highlighting the unique and entertaining aspect of running with the drone.
  Some runners indicated that focusing on the drone during their run was immersive and made them lose track of time. One participant stated, *"If you run two rounds normally it's just too boring, but with a drone, you're just focused on a point and the experience is going faster"* [P1]. Another participant mentioned, *"It seems to be longer than normal"* [P6], indicating that the presence of the drone had an impact on their perception of time.
- Drone Noise: Focusing on the drone's noise had a positive impact on some runners, allowing them to direct their attention/focus inwards and maintain their pace. One participant expressed, *"...you didn't focus on the environment, but only on the buzzing sounds, but it helped me keep the pace"* [P4]. Another participant mentioned, *"...I felt like I needed to hear where the sound is to feel if I'm doing the right thing or not"* [P3], indicating that the drone's noise served as a guiding element for their running pace.
- Drone Speed: Some runners highlighted the impact of the drone's varying speed on their overall experience. Specifically, they noticed how the drone adjusted its speed when navigating the curves of the track. This led to an engaging aspect of the experience, as they described it as playing a game of catch-up with the drone. One runner explained, *"In the first corner, I felt I had to go way faster than it used to follow it, and in the second lap, I was used to that, so it was easier to follow in the corner as well"* [P8]. Another participant described the experience as a *"weird game"* where they constantly checked if they were catching up with the drone

or if the drone was catching up with them [P9]. The same participant, however, indicated this also made them doubt their ability to maintain the pace; *"I think there's too much that I'm looking at [the drone] too often"* [P9].

- Drone Position: Given the position of the drone, some runners mentioned that it enhanced their enjoyment of the outdoors and made them more aware of their surroundings as they constantly looked up; *"I enjoyed the outside more because I was looking towards the sky"* [P9], and *"I felt more aware of what was happening around me"* [P3].
  One runner also mentioned that due to the drone's position, they occasionally had to turn their head, which they found to be a pleasant experience; *"But occasionally moving the head will be a nice experience"* [P6].
  Furthermore, one runner pointed out that because of the drone's position, it was challenging to track its location when the sun was behind it; *"The drone was exactly in the sun, so I couldn't look up and see where the drone was"* [P7].
- General Experience: Some of the generally positive comments were related to the novelty of the experience; *"... fun experience..."* [P4], *"It was nice and I think that it would be a really nice form of training"* [P6] , and *"... first time I did [running with drone], and I think was a interesting experience..."* [P5]

5 RESULTS & ANALYSIS 2: REFLECTIONS OF RUNNERS AFTER VIEWING THE DRONE VIDEO OF THEIR RUN

Drone videos proved highly beneficial for runners, enabling self-reflection on performance and gaining valuable insights into technique. Access to drone video footage offered practical advantages, facilitating convenient self-analysis and identification of areas for improvement. One runner found it easy and convenient to analyse their running form using videos allowing them to identify unnoticed aspects; *"...feel like there's my legs are not moving symmetrically... my upper body is a bit tilted forwards... there are definitely things I would change based on my own knowledge about running "* [P3]. Similarly another participant mentioned using the video in conjunction with their existing knowledge to adjust their running technique; *"...I can see my moving pattern... I think I would know how to maybe adapt a little bit or improve the running pattern..."* [P5]. Slowing down the videos for detailed examination allowed runners to identify and correct errors or areas for improvement, as emphasized by a participant *"...this bit of video can be slowed down... you can see like the slow-mo movements... and everything... better... like your mistakes"* [P6]. In addition to easy access and analysis, runners appreciated the convenience of readily available drone video footage. They no longer had to rely on lab settings or assistance from others to record their runs. Instead, they could easily review the drone-captured video for a comprehensive understanding of their running form; *"...before... to analyze, we have to be on a treadmill or in a lab or ask our family to take a video, and then we analyze. But now I can see this, the experience from top..."* [P8].

The videos facilitated runners in reflecting on their thoughts and experiences during their runs, leading to a deeper level of introspection. They could confirm observations like a constant downward gaze and distractions from the run through video validation. One participant expressed *"...I'm pretty much looking downwards all the time and it was confirmed on video... "* [P10]. Another mentioned *"...not thinking about how I run more about what I going to do with my schedule next like my to do list "* [P3]. The videos visually represented runners' thought processes and intentions during the run, including their focus on the drone and their position relative to it. They also captured moments when runners adjusted their pace to match the drone's movements or made adaptations based on environmental factors like shadows or sunlight. These reflections deepened their understanding of their running performance. Participants mentioned *"...thinking about the drone and that I'm not in the middle. And then I see it... "* [P4], *"... I have to slow down to match the pace of the thing that I can see. You can see that like the movement of my head and then I suddenly speed up or slow down..."* [P6] and *"...I could see I was moving a little bit outwards...I was thinking oh, I should move outward because there's this little bit of shadow ..."* [P10].

Furthermore, the videos offered valuable pacing feedback, alleviating runners' concerns about maintaining the right pace. They could see from the videos that their pace remained steady and centered throughout their runs, boosting their confidence in their performance. As one participant described, *"...I could see that I was running at a more steady pace than I felt I was..."* [P2]. Another participant echoed this sentiment, stating, *"...I think I'm almost every time in the middle. So then I had not to worry that much during the run..."* [P4]. The strong appeal and desire for the videos were evident among the runners, as many expressed interest in obtaining a copy for future reference and analysis. This eagerness demonstrated their recognition of the transformative impact drone videos could have on post-run reflections and the overall running experience.

But, there were some runners who expressed that the videos didn't provide additional insights into their running technique beyond what they already knew. They mentioned that the high angle and perspective of the video made it challenging to analyze their running form effectively. One participant noted that the video lacked a side view, stating, *"I think the video was quite high, so you're not really have the side view"* [P1]. Another participant mentioned the difficulty of assessing their technique from the top-down perspective, saying, *"...I think there are definitely things I would change based on my own knowledge about running. But I think it's hard to tell because it's filmed from above instead of like the side front"* [P3].

Additionally, the runners provided valuable insights on potential enhancements that could be incorporated into the videos to further elevate their self-reflection process. They emphasize the value of expert analysis combined with running data, as one participant states, *"the video itself it doesn't say much because when you see yourself running but it's not like the small details we can see, when we have actual data that is better"* [P1]. The integration of video analysis with running data and performance indicators is seen as crucial for a comprehensive understanding of performance. Another participant indicated the importance of peer feedback and not just coaches, *"So maybe you can improve your own running by watching but I think watching yourself is difficult because mostly you learn when other people say it looks weird what you're doing. I'm not sure if you're able to do it yourself"* [P3].

Slowing down the videos was also highly appreciated, allowing for detailed examination of movements and identification of mistakes, as one participant notes, *"this bit of video can be slowed down... you can see like the slow-mo movements... and everything... better... like your mistakes"* [P6]. Furthermore, the same runner believed that the captured video can be used to generate personalized training experiences to enhance running performance, as expressed by a participant who says, *"this will be also adding some more input to the training experience"* [P6].

6 RESULTS & ANALYSIS 3: ROLES AND FUNCTIONS FOR DRONES TO SUPPORT RUNNERS

This section highlights the varied roles and functions that drones can play in supporting runners, based on our analysis of participant responses. Through thematic analysis, we devised these roles to explore the broader applications of drone technology beyond the scope of our study. By delving into each role, we present the functions of each role and valuable insights for future research. The roles are presented in order of their supporting number of codes, emphasizing their significance and relevance.

- **AirTrainers** [25 codes]: This is a role that entails drones supporting runners in their training regimens. One of the drone's functions would be to help runners set varying precise speeds for interval training (*"... interval trainings ... I'm just trying to pace up myself and then keep that constant speed... "* [P9]) and understand their form at higher speeds (*"..when you're running, ... when you're going fast, it becomes more difficult to focus on technique. So it will be nice to be able to look at that at home and see form"* [P10]). The availability of drone videos had received positive reactions from runners, who indicated a desire for different video angles (*"...for sprinters then the side view is more important thing for long distance"* [P1], *"Would it be able to also film from different angles? Because for me, that will make a very, very big difference"* [P3], *"...you're not seeing the sideway so I don't think you can see the movements of the legs that well to really see if you have to change something"* [P4]) and combining visuals with information on their running form (*"...if you would know how to exactly improve the way you run then these videos could definitely help I think"* [P7], *"...better to just a little bit of focus on cadence or step length"* [P10]).
  Additionally, the runners mentioned that the videos would help them design better training sessions (*"...this [video] will be also adding some more input to the training experience because if you can see like the slow-mo movements you can then pause the video and everything you can see better"* [P6]). They believe that if trainers can use drone videos to develop tailored training activities and share them on social media, it can attract more trainees and improve their reputation in the training world (*"If this personal trainer have all the gadget that is the top one that not so many people have and this personal trainer immediately if he will stand out in the business"* [P8]).
  As AirTrainers, a drone should provide runners with the autonomy to change the position and speed of the drone. It should also allow runners to self-analyze their runs and highlight the small details in their movements, through dashboards (*"when you see yourself running but it's not like the small details we can see, when we have actual data that is better"* [P1]). Additionally, the drone should help conduct training similar to the convenience of a smartwatch (*"...because now I'm wearing a watch and my watch can determine my trainings and determine the interval trainings I make"* [P1]).
  To fulfil the role of AirTrainers, a drone should have software capable of detecting runners and their pose in real time. It should process pose information and derive various running parameters that can be communicated in real time or through post-hoc dashboards. In addition, the physical design of the drone should be carefully crafted to align with runners' preferences, prioritizing trust and likability. These factors play a crucial role in determining the adoption of technology within any context of usage [59].
- **Companion** [7 codes]: This is a role that entail drones entertaining runners during their runs. As one participant mentioned, they desired the drone to alleviate boredom by adapting music to their running or simply being present to provide cheer (*"I wouldn't expect it to repeat or direct me; I would just expect it to be with me, cheering me up"* [P9]).
  To fulfil its role as a companion, the drone could create a sense of agency by adjusting its positions and movements based on the runner's actions, while minimizing interference. For some runners, the ability to control the drone themselves is essential, especially when running in remote areas or requiring speed variations (*"...if I can control the drone myself without the other person because sometimes the runner they just go somewhere to do running..."*[P8], *"when you would like to slow down and speed up sometimes because I'm like, you know, feeding myself sometimes I'm drinking water and I slow down and then my heart rate. And then yeah, it becomes annoying because it [drone] will you know, go forward and then not really follow me"* [P9]). Alternatively, the drone could be tele-operated by an actual companion from a distance, making the interaction between the runner and the drone more realistic. Moreover, careful consideration should be given to the physical design of the drone to ensure it generates a positive effect and enhances the overall running experience.
- **Trail/Forest Drone** [4 codes]: This is a role that entail drones supporting runs that take place in wooded areas or forests. One runner expressed enthusiasm for the drone as a valuable device for trail running (*"It will be a really, really nice product. I think for both track running and trail running"* [P6]). While serving a similar purpose as the AirTrainer, the trail drone would offer additional benefits. The same runner highlighted the need for the drone to capture video footage during trail runs, as it can be challenging for cyclists or other individuals to run alongside and record videos on uneven and unpredictable paths (*"...more useful than the normal trainings because in the mountains you don't have places like to stay and film people so there is just a path through which you walk with a drone..."* [P6]). Furthermore, they believed it would be advantageous for the drone to map and analyze the terrain,

allowing them to plan optimal training regimens and routes (*"...also see the terrain, the track, you can analyse everything weather, do a better strategy. It will be a really, really nice product..."* [P6]).
However, researchers must consider that runners venture into forests to clear their heads and listen to internal and nature's sounds, preferring not to hear the noise of a drone. (*"...but if I'm running into forests, then I would love to clear my head and then I would rather not have the sound of the quadcopter"* [P3]). Therefore, in addition to providing information about the forest paths, it is essential to ensure that the drone produces minimal noise or allows the runner to control the noise, contributing to an enhanced running experience. (*"...reducing the volume of the drone would improve the user experience"* [P5]). Furthermore it is crucial for researchers to consider the necessity of incorporating advanced obstacle avoidance and navigation systems into the drone. These systems are essential to prevent the drone from crashing into trees or other obstacles while accurately following the runner through the forest.

- **Alerter & Navigator** [3 codes]: This is a role that entail drones to help runners stay alert and notify others while guiding them along a running track or path. One runner mentioned that the drone could assist in resolving conflicts with other track users by providing warnings or instructions (*"Sometimes you have conflict with the other guys using the track then he could so the drone could say hey, go out … or you want to overtake …. it can … help … alert them … give a warning sign"* [P4]). Another emphasized the benefits of having a drone during city runs to enhance their awareness of surroundings, especially in potentially dangerous situations (*"If I'm running in the city it's good to be aware of because then there's traffic and there could be dangerous situation."* [P3]). Another believed that being observant of their environment, including observing what happens on the streets, keeps them motivated (*"...observe what happens (dangerous incidents) in the street is quite keep me motivated"* [P8]). To fulfil this role, the drone should be equipped with functions that allow for alerting the runner or authorities in case of dangerous situations. There are various opportunities for researchers to explore different communication modalities, including incorporating speakers and connecting to haptic sensors.
- **Social Media Facilitator** [2 codes]: This is a role that entail drones supporting runners to record impressive videos of various training activities from different angles. One participant expressed that recording and sharing these videos on social media platforms could help trainers gain popularity and even generate income, especially when posted on social media platforms (*"...if you can show this video, you get a lot of respect. & .. earn your income as a YouTuber..."* [P8]). In addition to popularity and monetary benefits, sharing drone-recorded videos can enhance the credibility of trainers and users, positioning them as individuals who embrace new technologies to improve their routines. This association with advanced technology could add to their reputation and respect among peers (*"...drone most of time is used for the young boy they they want to do have a kind of get respect because it's a new technology… if you can show this video, you get a lot of respect within your friend"* [P9]).
- **Riveting** [2 codes]: This is a role that entail drones to help runners become immersed in the experience as facilitated by the drone, causing them to lose track of time. Participants mentioned that focusing on the drone during their runs made time feel faster and kept their concentration engaged (*"...you have to focus on something so it's time goes faster"* [P1], and *"I have to keep the mind on the drone too … usually when you are running, you're just concentrating on something. So if you're losing concentration with these little things, it seems to be longer than normal..."* [P6]). Researchers could take advantage of the immersive experience a drones' presence creates to manipulate the runners' perception of time. By designing interactions and incorporating temporal illusions, the drone could help create the impression that the runner has spent more or less time on an exercise, giving them a sense of maximum benefit or providing them with additional time to focus on other things.
- **Exergame Conductor** [2 codes]: This is a role that entails drones conducting games that drives exercises. During the experiential study, one runner indicated that they sometimes used the noise generated by the drone to maintain their pace, leading to a sense of engagement similar to playing a game (*"I was always constantly looking up to see if I'm catching up with it, or it's catching up with me. So it was kind of a weird game"* [P9]). Another runner expressed that the drone noise made them perceive being chased by a swarm of bees and even fostered a detective-like imagination as if in a movie set (*"...later I just tried to imagine I'm a detective in a movie set"* [P8]). Drawing parallels to existing applications like ZombieRun [16], drones have the potential to replicate such scenarios, enhancing exergames with their presence and diverse on-board sensors and actuators.
- **Behavioral Catalyst** [2 codes]: This is a role that entails drones acting as a catalyst to influence and inspire the runner to change their behaviour and adopt a new approach to self-monitoring, facilitated by the presence. One participant had indicated that the drone had changed the way they checked on themselves (*"[the drone following them] had kind of a positive effect because I kind of thought about myself and what I'm doing at the moment and got me think about what I'm doing and how I do it at the moment"* [P5]) and replaced their behaviour of monitoring their pace using their smartwatch (*"...it replaced my watch checking behaviour … I didn't check my speed at all [on watch]. I was just checking it and then in that sense, maybe like we can say enjoying the outside more"* [P9]). This highlights the potential of the presence of external systems like drones to transform self-monitoring practices during running.
- **Sightseeing Coach** [1 code]: This is a role that entails drones to help runners discover new places or explore unfamiliar trails while also acting as coaches. One runner mentioned that the drone's position, when running with the drone as a pacesetter, enhanced their enjoyment of the

outdoors during their runs (*"...enjoying the outside more because I'm looking towards the sky..."* [P9]). Drones can be programmed with waypoints to guide runners to locations they may find appealing, both within the city and in scenic outskirts like wooded or forest trails. Moreover, when combined with the AirTrainer function, drones can provide coaching support while runners engage in their outdoor activities.

7 DISCUSSION

Upon analyzing the runners' responses to their experience running with a drone as a pacesetter, we determined that they found the experience to be engaging and found the playback of the drone video recordings from their runs valuable in supporting their post-run reflections. Additionally, through our interviews with the runners, we discovered the potential for drones and drone videos to be further utilized in fulfilling various functions that runners require, as well as enhancing their post-run reflections. We now delve into the benefits, future considerations, and limitations of our work.

Supporting Interval/Pace Training: Based on our work, it is clear that runners find running with a drone to be engaging. By addressing the shortcomings we identified in our study, drones have the potential to support interval/pace training. Although we did not directly compare this method with traditional approaches, our findings provide strong evidence in favor of using drones for such training purposes. We plan on further exploring the utilization of drones as interval trainers by investigating the range of training programs they can support compared to traditional methods, investigate the interaction design considerations for such drones, and study the proxemics between the runner and the drone for this use case. Furthermore, the insights we have gathered from our study aim to serve as an inspiration for future researchers. We hope our work encourages them to design and test interactive scenarios tailored to supporting runners during interval and pace training.

Designing Dashboards to Support Reflections Using Drone Videos: Based on the reflections of the runners, it becomes evident that they would greatly benefit from having a dedicated dashboard to process and analyze the drone video recordings of their runs. While our work already demonstrates the value of using unedited and unprocessed videos for post-run reflections, we believe that enhancing their reflective experience is possible by incorporating additional features into the dashboard as suggested by the runners. These features could include options for viewing the running videos in slow motion, controlling playback, highlighting key moments, and presenting meaningful running data in a user-friendly interface that indexes events of interest or allows runners to search for specific instances using key terms, enabling them to augment their reflections even further. By leveraging AI tools [DeeperCut [20], DeepLabCut [30], DeepPose [57], AlphaPose [15], OpenPose [8], OpenCap [58]], videos can be utilized to estimate poses and running parameter, thereby providing more valuable insights through a dashboard. A deep learning model can also help minimize the reliance on expert intervention, such as a coach, by leveraging pattern analysis in running data to detect and address problematic areas more autonomously [24]. However, further investigation is necessary to fully explore the potential of this approach. To ensure such a system's effectiveness and usability, input and feedback from both coaches and runners should be considered during the development process. By incorporating their perspectives, the system can be tailored to meet the specific requirements and preferences of the users, maximizing its impact. As part of our project, we plan to conduct further interviews with additional runners to gain a deeper understanding of the information they would like to see on a dashboard and to explore the characteristic of their preferred ways of interacting with running data.

Roles & Functions for Drones: The roles and functions of drones were derived based on the insights provided by runners regarding how they envision using drones in specific scenarios. The naming of these roles were thoughtfully chosen to encapsulate the common codes identified in the data, and the functions assigned to them were directly shaped by the input of the runners. It is important to note that these functions need not exist independently; they could overlap and combined with the others. For example, a drone may simultaneously assume the roles of guide and companion, particularly in settings like trail runs. Our intention is to provide a solid foundation for future researchers, enabling them to better understand the requirements of runners. We believe that these insights into the roles and functions of drones, as informed by runners experiences with a drone, will be valuable in guiding the design and development of drone technologies, that cater to various types of runs. By considering these, future endeavors in this field can be better aligned with the expectations of the running community.

Longitudinal Studies with Diverse and More Participants: Our initial results are promising; however, to draw definitive conclusions on the long-term adoption and usage of drones, as well as how they may complement or compare to existing running technology, conducting longitudinal studies involving a more diverse group of runners is crucial. Over time, factors like technology novelty wearing off or the experience becoming less engaging could influence runners' interest in drones. Through longitudinal studies, we can gain deeper insights into the specific factors contributing to this potential decline and work towards addressing them in future designs.

Furthermore, a larger participant sample would have significantly improved the quality and breadth of our findings. Our study's recruitment criteria were tailored to align with a parallel study, leading to a specific subset of runners being included [1]. This subset may not have represented all possible perspectives on drone technology, potentially biasing our recorded opinions. By including a broader range of participants and recording additional running characteristics, such as technology adoption, motivation, and habits, we could have unearthed the underlying reasons behind their opinions. This, in turn, would have enabled us to provide more robust design recommendations for drones, catering to a broader spectrum of runners.

It's important to underscore that our study's primary goal was not to make sweeping generalizations but rather to offer valuable insights within a specific context. As such, our findings should be

[1]In order to align with our parallel biomechanical study, we specifically recruited participants who met certain running criteria. These criteria included the ability to maintain a minimum speed of 13 kmph for at least 5 minutes, continue running until reaching exhaustion, and have no prior injuries

interpreted within this context, and any extrapolations to wider populations should be approached with caution.

Study Design Limitations: For ethical reasons, participant safety was a top priority while operating the potentially harmful drone. Maintaining a safe distance between the drone and the runner was crucial to allow the pilot to assume control in case of emergencies without endangering the runner. However, positioning the drone in a way that required runners to frequently turn their heads to the right and look up had a negative impact on their experience. This aspect, highlighted during the interviews, may have influenced their perception of running with the drone.

Factors Evaluating Experience Running with Drone: In retrospect, based on our qualitative analysis of the runners' experiences and evaluating the results obtained from our chosen questionnaire, we realize that additional questions and factors should have been included and some removed to comprehensively assess the runners' experience running with a drone quantitatively. Specifically, we acknowledge the need to incorporate factors related to physical exertion, cognitive process, and drone-related aspects in order to obtain a more comprehensive evaluation of the experience. This realization suggests that there is an opportunity for further research in this area, with the goal of developing questionnaires that effectively evaluates physical exertion experiences mediated through a drone. We hope that the insights we derived from the runners' experience will contribute to the development of such a questionnaire.

Overarching Ethical Concerns: Using camera drones, whether in research or commercial contexts, entails ethical considerations. While some of these considerations may not directly align with our study's focus, we acknowledge the importance of addressing relevant ethical aspects. Recording videos in public spaces with drones can unintentionally capture data beyond the intended scope, including bystanders and private properties. Our study took precautions to avoid such unintended data, but further advancements are needed in system design to discard unnecessary recordings and ensure privacy. AI technology can aid in developing drones that selectively record only the intended subject while masking unintended data [5, 52]. Additionally, addressing the issue of communicating with bystanders to ensure they are aware of not being recorded is an area that requires exploration. Stringent laws regulate the use of drones weighing over 250g in various countries for safety and privacy reasons. To comply with these laws, drone operators must obtain a remote pilot license. While our research study had a licensed team member, future drone market offerings for runners may require individual licenses. However, advancements in technology miniaturization, sensors, motors, and batteries can enable development of smaller drones weighing less than 250g [33, 55]. This would grant runners greater freedom as sub-250g drones are often subject to fewer restrictions due to their lower potential harm. In future implementations, researchers should also consider additional factors related to navigating around bystanders or buildings and the utilization of such systems in uncontrolled environments.

8 CONCLUSION

In this paper we showcased that incorporating drones to conduct a simple pacing exercise can create an engaging experience without significant negative consequences. Our qualitative analysis of the interview responses provided valuable insights into the factors that contribute to runner enjoyment and those that may need addressing. Moreover, the runners' suggestions regarding the utilization of drone videos for post-run reflections highlight the benefits associated with drone technology. The insights gained from their responses guided the formulation of potential roles and functions for drones, suggesting promising avenues for future research. Building on the findings of this study, our future research endeavours will involve conducting a more comprehensive study that compares the effectiveness of utilizing drones to support advanced pace training regimens with traditional methods. This will provide additional evidence supporting the practicality of drones in assisting with outdoor pace-related training. Lastly, we also plan to investigate the design of dashboards for post-run reflections that enable easy identification of problem areas and showcase key actions through accessible drone video highlights, motivating runners to improve their training regimens.

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