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Drones as Accessibility Probes in Able-Bodied Norms: Insights from People with Lived Experiences of Disabilities

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ABSTRACT

We present an exploratory, in-the-wild study in which a small hobby drone and a game controller were freely used by five people in their domestic environments, indoors and outdoors. All participants had motor disabilities affecting their arms and hands, and two also used wheelchairs. One participant contributed as a community researcher, assisting in data analysis, reflecting on findings, drawing conclusions, and co-authoring this paper. The findings reveal several usability and accessibility issues, along with potential risks and opportunities for the use of hobby drones in everyday situations. Beyond these insights, we discuss the importance of including people with lived experience of disability in research to shape a holistic and inclusive understanding of the use of mainstream artifacts such as hobby drones. This also helps prevent able-bodied design norms from limiting who can use drone technology and how it is used.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in accessibility**; **Accessibility design and evaluation methods**.

KEYWORDS

hobby drones, disability, impairment, usability, accessibility, probes, HDI, ethnography, interviews, inclusive design, lived experience, strong objectivity

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1 INTRODUCTION

Against a backdrop of increasing integration of Unmanned Air Vehicles (UAVs) or drones in various industries and hobby practices, this paper presents an in-the-wild study centered on the experiences of

Figure 1: Sketch of a participant sitting on the ground outdoors using her feet to maneuver a DJI mini drone (Tello) with a GameSir controller. Her smartphone, which functions as a screen, is placed on a bag next to her.

individuals with motor disabilities in their arms and hands exploring the use of a mainstream hobby drone in their everyday environments (see Figure 1). The primary objective was to uncover nuanced perspectives and challenges faced by such users without imposing preconceived notions or staging use case scenarios. Experiences from this user group remain relatively obscured within the hobbyist drone field. A recent study on the role of humans in Human-Robot Interaction (HRI) found that very few research papers in this field involve collaborating with people with disabilities [41]. This phenomenon is not only problematic due to the overlooking of significant insights but also signifies an inequality in whose experiences are investigated, and whose are disregarded. In addition, the absence of active participation through the involvement of such individuals in formulating research will inevitably influence the research landscape, creating a risk that important perspectives, interests, and knowledge may be overlooked. To this end, two separate packages to facilitate hobby drone piloting were

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distributed to households. The first package contained a GameSir joystick remote controller, and the second a small DJI Tello hobby drone. The participants' interactions with the controller and drone were closely documented through semi-structured interviews. Insights were obtained by focusing on elevating and understanding the users' experiences as they freely explored the use of the drones; this revealed previously unrecognized accessibility and usability opportunities, and thus contributed to a more holistic and inclusive understanding of drone usage. The central question driving this work was: "How can the user experience, interests, and reflections of individuals with impairment or disability needs inform our understanding of drone-related challenges and opportunities?"

Involving people with disabilities needs in the design of mainstream products and societal infrastructure solutions rather than just in designing assistive technology (a generic term referring to both services, products and equipment, adapted, modified or developed to increase, maintain, or improve individuals' functioning and independence, see for example,[19]) is an important element of inclusive design and social design. In 1971, Papanek[58] emphasized that efforts to develop good design will benefit if designers look at real human and societal needs (rather than wants) and recognize that these needs are particularly salient among marginalized people. Designers have a great responsibility not only to produce accessible designs specifically tailored to marginal groups (i.e people with disabilities) but to create accessible mainstream solutions. As Margolin and Margolin [45] put it:

> Inadequate or inferior physical surroundings and products can affect the safety, social opportunity, stress level, sense of belonging, self-esteem, or even physical health of a person or persons in a community. [45]

Methodologically, we take inspiration from cultural and technology probes [39] ethnography and autoethnography (see e.g [25, 59]), and community researchers (see e.g. [51]). In these methods, lived and embodied experience acts as the lens through which the world is viewed and establishes the research as a position where the researcher's personal experiences may clarify, extend, mirror or even clash with those of other participants. With a foundation in feminist standpoint epistemology [31][32], we challenge the conventional scientific understanding of value-free objectivity. This perspective contrasts with that of traditional scientific research based on creating a conscious distance between the researcher and subject to increase objectivity, which is said to authorize the produced knowledge. Feminist stances [32] have shown that this assumption of objectivity is often wrong as nuanced details can actually protect us from our own prejudices. Furthermore, there are risks of misunderstandings and becoming lost if direct and open engagement with the participants is not sought or created [37]. In reaction to this, Harding [33][32] coined the term 'strong objectivity' to describe a way of maximizing objectivity by advocating for inclusive and socially aware scientific inquiry that considers the diverse perspectives and experiences of different individuals. Knowledge from marginalized groups [30] such as people with disability needs in arms and hands is vital for improving scientific research, scrutinizing privilege, mitigating societal inequalities, and enhancing the objectivity of inquiry [32]. While 'strong objectivity' is not a term that is used or adopted universally in Critical Disability Studies (CDS) literature, a core principle of CDS is to incorporate diverse perspectives to highlight the social construction of disability, question normative assumptions, and advocate for a more inclusive and equitable society. It thus aligns with strong objectivity's broad aim of challenging traditional biases and suggests that objectivity can be enhanced by incorporating the perspectives and experiences of marginalized groups, including women, to provide a more comprehensive and less biased understanding of a given subject. In research, people with additional physical or cognitive needs, elderly individuals, and children are often referred to as vulnerable participants (see for example, [64]) or marginalized user groups. However, there appears to be a lack of international consensus on the definition of a 'vulnerable participant' [13], with its meaning being individual and context-dependent.

1.1 Author positionality

Author 1 Pamela Lindgren has an Master of Fine Arts (MFA) and is an active professional product and industrial designer, consultant, and PhD student focusing on user acceptance and adoption of assistive technology for individuals with disabilities. This author has over 29 years of lived experience of impairment and disability needs.

Author 2 Sara Ljungblad is associate professor in Interaction Design and has a Ph.D. in Human Machine Interaction. She has been active in the field of Human Computer Interaction (HCI) since 2003 and in HRI since 2004 and in HDI since 2020. This author has a strong research interest in design methodology (after spending three years at a design and innovation agency), as well as in inclusive design and human-robot interaction. She does not have experience of long-term motor disabilities.

Our work aims to achieve 'strong objectivity' in part, by positioning one author simultaneously as a product designer, community researcher, and participant, thereby increasing the diversity of author voices within HRI while also contributing with knowledge and expertise not just as a designer and researcher but also as a woman with impairment and lived experiences of disability. Our work thus resonates with feministic HRI [75], inclusive design, critical disability studies (CDS) (e.g.,[70]), norm critical approaches ([48]), and related context-sensitive research that promotes diversity.

2 RELATED WORKS

In recent years Unmanned Air Vehicles (UAV), or drones, have become widely integrated in many industrial working practices [43], hobby practices such as photography [36], and other playful and creative 'everyday hacking' practices [60]. The area of Human Drone Interaction (HDI) is relatively new, so emerging hobby practices are largely unexplored, especially from the perspective of children [25] and people with disabilities.

2.1 Accessibility and drone use

Accessibility typically means the ability to access something without barriers despite individual variations in motor control, vision, hearing, and so on. An accessible interface is perceivable, operable, robust, and understandable [74], but accessibility can also be affected by factors such as a product's packaging and installation instructions [20]. Accessibility and usability go hand in hand as

both can improve a variety of use situations. Unfortunately, accessibility has received relatively little attention in drone research (e.g. [35, 40, 72]). Limited knowledge of accessibility and usability introduces the risk of creating products that favor certain types of users over others, such as people with disabilities, leading to potential exclusion.

Like all technological products, drones are created with values, biases, and standpoints [23] that are connected to specific moral decisions and ethics [73]. This is important to consider because some user groups may be disenfranchised by particular kinds of technological arrangements [67]. Mirri et al.[50] and Cauchard et al.[17] list opportunities and challenges facing the HDI community that will drive future research, including ethical considerations, dealing with increasingly autonomous drones, drone use in public spaces by users who are increasingly likely to be lay persons rather than experts [17], and the need to explore drones' great potential to enhance the quality of life of diverse individuals, including those with disabilities, in different situations and everyday settings [50].

A recent overview study on HDI highlighted gesture, speech, multimodal, and touch interfaces as well as Brain Computer Interfaces (BCI) as modes of drone interaction that could improve accessibility, but noted that such interfaces are currently used mainly in labs [72]. Another study mentioned BCI as an interface type that could provide opportunities for people with disabilities, but noted that it has limited fidelity and robustness and is currently unsuitable for study outside the lab [53]. Garcia et al.[26] have extensively investigated adapted ways of maneuvering a drone including adaptations at the hardware, software and automation levels to accommodate different combinations of cognitive, motor, visual and speech impairments [26, 27]. Their studies are based on a collaboration with people with disabilities who had joined a drone piloting association. Drone interaction was studied in a controlled environment, leading to the development of an interactive application that supports ad-hoc interaction by leveraging hardware, software, and automation adaptations in order to support drone piloting as a leisure activity that can be integrated into therapy as an enjoyable exercise [26].

Three studies involving one to five participants with visual impairments have also tested drones as assistive aids to help blind and visually impaired people navigate [3, 5, 6]. One of the three studies (using a Wizard of Oz style) found that the participants were: "uncertain about their ability to follow the drone while running, and uncertain about the role that drones might play in assisting them with their own physical activity" [3, p.264]. Gadiraju et al.[24] surveyed visually impaired adult drone users and performed interviews to understand their expectations of drones. This revealed that drone piloting appealed to the participants because it related to their interests in aviation, exploring new technology and environments, and finding activities to do with their sighted family members. Finally, a study on Tello drones conducted by Popova et al. [61] treated vulnerability as an ethical stance, exposing discomfort and perceived risks from bodily and methodological perspectives. However, no participants with impairment or disability needs were included. Beyond the body of work discussed above, the literature is missing nuanced and holistic perspectives from people with disabilities who have more openly tested and reflected on the use of hobby drones in their everyday environments.

2.2 Critical disability studies

Critical Disability Studies (CDS) is a growing area of academic research that derives from disability studies (see e.g. [7, 37, 57]). It builds on the foundation of the disability rights movement [49], the movement slogan 'Nothing about us, without us', and the book by Charlton [18] with the same title. CDS perspectives draw on the experiences of individuals with disabilities to critically reflect on societies and foster discussions of disability and disablement while 'integrating new and transformative agendas associated with postcolonial, queer, and feminist theories' [28] in [29, p.190-191].

There are several models of how disability is seen in society, of which the social and medical models are most prominent. In the medical model people with impairment and disability needs are defined by their impairment or disability, which should be 'fixed', 'cured' or 'changed' by medical and other treatments (see e.g. [15, 46]). Contrasting this view are the 'social model' and 'cultural model' of disability, in which people with impairment or disability are seen as disabled by problems arising from design and different forms of social oppression ([54–57, 69]). A related model grounded in disability activism is Crip Theory [48], which is associated with the Crip movement and seeks to challenge normative notions of able-bodiedness to redefine perceptions of disability and promote inclusivity and accessibility. Crip theory critically examines and deconstructs cultural, social and political constructions of disability and particularly emphasizes the diverse experiences of individuals with disability to foster a more inclusive society.

2.3 Exclusion and non-use

Exclusion may occur if a product requires a certain type of use that is impossible for some to perform [21]. Satchell and Dourish[67] describe different types of non-use, including active resistance, displacement, and disenfranchised non-use. Active resistance can occur when technology becomes a symbol and means of changing a social system to a less desirable future, while displacement occurs when technology is skewed towards certain user types such as the middle class or the mobile young population without disability needs [67]. In disenfranchised non-use, specific social groups that are distinguished by economic, social, infrastructural, or geographic factors are disenfranchised by particular kinds of technological arrangements [67]. Non-use can thus be an active and motivated choice or a structural result, so studying the specifics of a given instance of non-use can provide nuanced insights into technology use and non-use. These perspectives can also serve to incite challenges to disablism and help explain why people with disabilities are often overlooked in research [11].

2.4 Disability and design

Design solutions can both cause exclusion and remedy exclusion, as discussed by Holmes[38]. They can be inclusive and accommodating for individuals with disabilities, enhancing their experiences with products, services, and environments, without categorizing bodies and without having predetermined limits regarding who they are for [21, 34, 38, 44, 52, 62]. In a study on the use of assistive technology, Shinohara and Wobbrock[71] identified several misconceptions about differences between assistive and mainstream

technologies that produced socially constructed ambiguities concerning what it means to have a disability and to what extent assistive technology can reduce and address experiences of disability. They argue that:

> "...if people with disabilities use the same technology as everyone else, perceptions of what they can and cannot do may be re-aligned" [71, p.713].

People with disabilities and other marginal groups can successfully contribute to design not only by creating assistive technologies intended for people with specific disability needs but also by supporting inclusion via so-called "Curb-Cut Effects" that benefit several different groups in society [10]. In general, a curb-cut effect occurs when a solution intended to help one group of users is subsequently found to benefit a wider range of users in more diverse situations than initially anticipated [12] [47]. The original example of such an effect occurred when curb cuts, which provide smooth connections between pavements and roads, were introduced to benefit wheelchair users but subsequently proved to be a universal design solution that also helps people using strollers and walkers. Audiobooks provide another well-known example: they were initially designed for vision-impaired people but are now used by diverse groups of people with reading difficulties as well as for pure entertainment and in situations where an individual's hands or eyes are occupied, such as when driving a car[66].

3 METHOD

At the time of the study, there were no commercially available accessible drone controllers, which was notable given our objective of investigating the usability and accessibility opportunities and challenges presented by an existing mainstream product. Study participants were therefore sent two gift packs roughly two weeks apart, one containing a controller and another containing a Tello drone. This drone is a lightweight but advanced mini drone that can take pictures and record video, and was chosen for safety reasons as the participants would be beginners.

3.1 Controller giftpack and first interview

The first package contained a GameSir T1d joystick remote controller. This package was sent to 'probe' and closely observe participants potential accessibility and usability issues with the joystick only, while introducing how to maneuver hobby drones. This approach supported conducting an online controlled observation session of the participants where they in a video interview would try out some tasks on the controller and reflect on the difficulty of these, before exploring piloting on their own. The controller is 7.10 cm long, 17 cm wide, and 12.80 cm tall, weighing 453.60 grams.

3.1.1 First interview. Before conducting the interviews, the researchers held a remote meeting with a physical therapist who gave feedback on the questions.

Each participant was interviewed by the researcher and an assistant via Zoom after receiving the controller. The interviewer showed participants introductory videos explaining how to use a more advanced drone (DJI Mini 2) outside, during which the participants rated the difficulty of performing the tasks shown on the video with their controllers on a scale ranging from 1 to 10. The tasks (related to general hobby drone use) were:

- 1) Mounting a phone on the controller
- 2) Unfolding the drone's arms
- 3) Starting the drone
- 4) Flying up, down, right, and left
- 5) Filming and taking photos
- 5) Landing the drone
- 6) Unscrewing the control sticks

When possible, the participants were encouraged to mimic each task on their controller by pressing the relevant buttons or moving the joystick, and to reflect on its difficulty. This took 15 minutes, after which the participants were asked open-ended questions about their experiences of and preferences concerning drone use, smartphones and assistive technology use (i.e if they used accessibility features on their phone), and previous joystick usage. Each interview took around 45 minutes.

3.2 Drone gift pack

The second package sent to the participants contained a Tello mini drone and basic safety instructions for general hobby drone piloting. The drone has a camera, allowing the user to see the view from the camera on their smartphone, take pictures (1280 x 720 pixels), and stream video. It is controlled with a Tello app on a smartphone or tablet using Bluetooth, or with the GameSir controller. One rechargeable battery provided a maximum flight time of 13 minutes. The drones were 9.8cm long, 9.25 cm wide, and 4.1 cm high, weighing 87 grams. Their maximum speed and flying altitude were 8 meters/second and 30 meters, respectively. The decision to opt for a small lightweight drone was driven by safety considerations - specifically, a desire to minimize potential harm or injury in the event of a collision with people or objects.

The choice of drone was based on safety considerations, which implied a need for low weight and a limited maximum speed and maximum flying height, as well as ease of access in terms of not requiring a drone license. In Sweden, all drones other than toy drones without cameras are classified and regulated based on their weight and capabilities. If used outdoors and equipped with a camera, a phone number must be attached to the drone along with the name of the registered drone operator.

3.3 Participants

Four participants between 50 and 65 years of age were found through the organization The Swedish Thalidomide Society (FfdN). FfdN is an organization originally established for children born with disabilities due to the drug Neurosedyn (thalidomide). Its members include persons with different congenital limb deficiencies or amputations of more than one arm or leg caused by injury or disease, with related motor disabilities that may include partial or total loss of function of a body part, poor stamina, low muscle control, muscle weakness, or total muscle paralysis. FfdN distributed invitations to its members asking them to participate in a research project on hobby drones. Four people responded and agreed to participate.

All participants expressed interest in piloting drones and taking part in the research project, and all had some arm or hand and other motor impairments. The four participants were given fictive names.

Agnes and James live together and shared a drone. Agnes used her feet and toes to interact with the drone. James used his hands to interact but without thumbs and arms. Jennifer uses a wheelchair and interacted with limited hand mobility without the use of thumbs. Ruth used her feet. None of the participants had cognitive disabilities. The study is connected to a larger research project on hobby drone use in society, including people with and without disabilities, which is approved by the Swedish Ethical Review Authority, Dnr 2022-07165-01.

3.4 Author participation

The first author (aged 55 years) was invited to join the study as both a fifth participant and a co-author. Pamela uses a manual wheelchair and controlled the drone with her arms and hands using gross motor skills. As such, she was able to support the project using her experiences of motor disabilities while also serving as a researcher and contributing to strong objectivity by acting as a community researcher and ensuring that stereotyped perspectives of people with disability needs were avoided when articulating the research. This set up is inspired by approaches such as community research (see e.g. [51]), autoethnography (see e.g. [25][65]) and experience reports, where an author acts as a participant and describes their first-hand experiences and reflections on use. This complements the data collection process and can reduce the distance to the participants because the author's lived experience helps them to relate to other participants and provide more nuanced and situated reflections.

3.5 Research design and data gathering

The research design was created and implemented by the second author and an assistant. Before the study a risk analysis was done. Based on this, and current drone regulations, initial safety instructions were created for the participants. Participants in three households were initially sent a consent form. Once they had agreed to participate, they were given first a controller and then a drone, as long-term hand outs and subsequently completed two or three follow-up interviews. The goal was to understand the participants' experiences when using a hobby drone in their everyday environment. Pamela's consent form, controller, and drone were delivered in person by the second author. All participants except Pamela had the controller for two weeks before receiving the drone. First, the controllers were sent to the participants' homes and preliminary interviews were conducted. Next, the Tello edu drones were sent and another one or two interviews were conducted. The material given to participants included consent forms and rules and regulations concerning drone piloting in Sweden. The first interview focused on the controller's usability and included videos showing how to start the drone, charge it, maneuver it, take pictures and film, and so on. The drone was then sent, and the two following interviews focused on the overall experience of using the drone. These interviews addressed topics including what the participants had done with the drone, and their experience. They were also asked if they would like to use it for something specific, and if it added any value. All interviews were conducted using Zoom or Teams by a research assistant, who arranged the interviews with the guidance and participation of the second author. The only exceptions were the two interviews conducted with the first author, where the second author was the interviewer. The interviews lasted from 45 minutes to 1 hour and were audio recorded, AI transcribed, and finally corrected by both authors. After the second interview round was completed the participants were allowed to keep the drone they had used, and four of them chose to do so.

For safety reasons, during the study's initial set up, each participant was not only given a set of safety instructions as a precautionary measure. They were also asked to make a family member or someone else register as a drone operator at the Swedish Transport Administration, taking full responsibility for safely piloting of the drone and assisting the study participant (when he or she piloted). However, these initial ethical measures for safety did not match the participants' own preferences or their understanding of their capabilities and the overall situation. Once this issue was raised by the participants, the requirement for having an operator present when piloting was removed, and the participants themselves could registered as the operator if they wanted to. In addition to the interviews, the participants were asked to provide photos and video taken with the drone by themselves or by a present person.

3.6 Analysis

An inductive thematic analysis [14] was conducted by the two authors using MAXQDA 2020. The process involved listening to the audio recordings, creating transcripts and reading the transcripts to become familiar with the material and then carefully reading and coding each transcript. An open inductive coding method was used where data-driven codes were identified individually and free-coded without any explicit protocol, generating a total of 2243 codes. Only one participant sentvideos to the research team, so videos and pictures were not part of the analysis.

Many codes concerned aspects of steering and handling the drone, accessibility, outdoor operation, and picture taking, resulting in themes (i.e., planning to fly the drone, picture taking opportunities, concerns about breakdowns etc.) that were defined using thematic analysis methodology Braun and Clarke[14].

First a transcript was coded line-by-line by the two authors jointly in the MAXQDA program to generate initial codes and openly discuss the material. The remaining interviews were then coded by the first author. The authors met to discuss and analyze the codes and specific parts of the material, adding new codes if needed and collating codes into larger categories to form tentative themes. The procedure was iterative and allowed for codes to be added, discussed, refined, and adjusted. After every transcript had been coded and analyzed, they were read and coded a second time by the coding author to verify that the coding was consistent with the identified and confirmed codes, categories and themes, following a hermeneutic tradition of data analysis.

4 FINDINGS

For clarity, the findings are sorted to first provide an overview of the preparations for using a drone, i.e. Unpacking, Assembling, and Setting Up. We then describe the themes based on the participants' experiences and reflections when planning to fly the drone, operating and steering the drone, their views on picture taking

opportunities, concerns about breakdowns, and finally reflections on spaces suitable for flying.

4.1 Unpacking, Assembling, and Setting Up

The controller and drone came in their original packages. To use them, participants had to unpack them,and attach the drone's propellers. Pamela described needing assistance to unpack and attach the propellers. Regarding the introductory videos of the more advanced drone (DJI Mini 2), she assessed it difficult to unfold the wings.

All participants reported frustrating and time-consuming difficulties due to technical issues with processes such as connecting the drone to Bluetooth technology and WIFI: "But what annoys me is that it falls out, and you have to start over with this (button) pressing, and that causes you to lose your appetite (for using it) a bit." (Jennifer). ´The technical procedure of getting the drone to fly and uploading photos and videos was also perceived as arduous: James said "We held on for as long as possible", while Agnes recalled that "We were trying to get it to start but the drone was sitting still on the table, it just didn't jump up and go." Learning how to use the drone by reading the instruction manual was described as difficult, particularly due to the lack of a Swedish version: "Because the instruction book, well, I would say, is pretty useless. Primarily this is because everything is terribly small (to read). We had to use glasses and a magnifier to read, and you should not have to do that, it's idiotic to make them like that."However, after using aids to read, the instructions were described as okay, according to Agnes. James thought the drone's charging cable was too short:

> "It was terribly annoying, especially (...) if you have a disability that means you have limited range, it's completely crazy to have such a short cord."

Pamela, Ruth and Agnes found the start button located between the drone's propellers difficult to reach; Agnes used a pen as a tool to press it to start: "It's like you'd need a fingernail to poke it a little bit more." (Agnes) Pamela also found the start button on the drone difficult: "If I had some tool maybe it would be easier to poke it in, but it's difficult. ´´ She would prefer starting the drone without the need to press a button. She needed assistance to connect the charger and press the drone's start button.

4.2 Planning to fly the drone

Some participants needed more time than others when planning to use the drone because they had to decide where to sit and use it, and adapt the chosen place to fit their individual needs. Ruth explained that:

> "Then you have to take it with you and plan and maybe set up a place where you can sit when using it. Because that's the problem. I can't just stand somewhere, I have to sit down and take out and drive with my feet (...) without wearing shoes and socks."(Ruth)

The drone's maximum flying time was very short (less than 13 min), which affected the users' enjoyment once everything was set up, not least because setup and learning how to use the drone took up a significant portion of the available flying time.

4.3 Operating and Steering the Drone:

Several participants used the drone while sitting down so they wanted to place the controller somewhere rather than holding it and to have the screen stood up separately. For Ruth the steering itself (which was done using her feet) was not difficult, but learning how to maneuver the controller steering the drone was perceived as difficult:

> "you don't really connect what is right and left. Forward, backwards, up and down was no problem. (...)...To spin it, no problem, but it's right and left that I have a bit of difficulty with, and the sides as well. The right side is more difficult because you kind of don't connect the brain properly. Because you would probably want to drive to the right if you pull the lever to the right then you would want it to go in that direction, but that is not the case; instead, it goes sideways."

Every participant lacking fingers or hand function found it difficult to use the double command on the controller, which requires the user to press two buttons simultaneously. As Agnes put it:

> "So I would have to press two (buttons) at the same time, next to each other. Yes, I could do that (...) but then I would have had to put it (the controller) down on a table or on the ground (...) I wouldn't have been able to hold it at the same time."

In addition, the controller's buttons were described as too small and too close to each other or sometimes too far apart, and required fine finger precision and a suitable hand size to operate as intended. For example, Pamela stated that the buttons were poorly placed for her needs: "...because I kind of have to let go of the joystick then try to push, as I can't press the button with one finger but only with the whole hand....I don't have that grip, the index finger grip you kind of need to hold it." Ruth wanted "...to have a simpler button for filming, they are so small now." Jennifer described being confused about the meaning of the controller button's light color: "It glows in different colors. What does this even mean?"

Overall the joystick controller was perceived as being too big and heavy. Pamela had the joystick in her lap and described difficulties accessing her phone: "It will be difficult to access the mobile at the same time, I have to put the joystick down to access it." James described difficulty in gripping and holding the controller, needing assistance to carry the drone or an additional belt to support it: "For me, who has short arms, (I need) to have some kind of belt around the upper body so that you don't have to hold it".

Both Pamela and Jennifer wanted more flexibility in the joystick's fine-tuned steering precision options as the joystick was perceived to be too sensitive to movement, which negatively affected maneuvering and steering precision. For example, Pamela described how gross movement and spasticity impacted the steering. Ruth noted that practice was needed to get used to flying the drone and compared this to her experiences of playing video games: "So that's the only thing that takes a bit of practice, but it's like playing TV games... I think it's almost as exciting. And when you look at the phone then you see how it flies away, it's actually quite exciting." Ruth and Agnes had piloted the drone indoors but said that more practice was needed to learn how to fly the drone without crashing into doors, objects like lamps or plants, or people: "It was

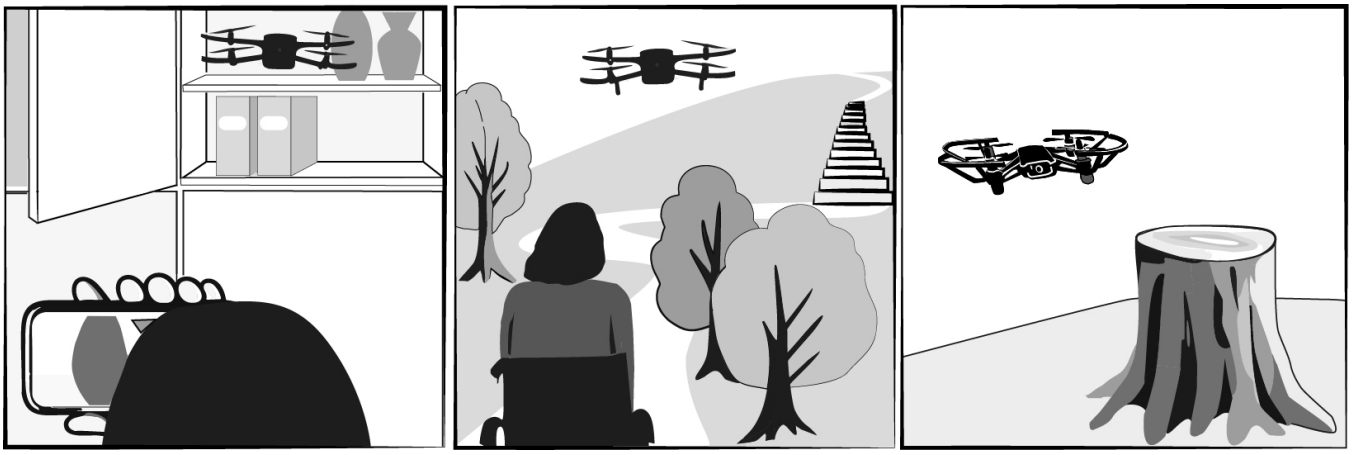

Figure 2: Sketches of imagined use of drones, revealing accessibility issues. Filming objects in a high cupboard (left). Checking potential wheelchair inaccessibly outdoor environments from a distance (centre). Picturing a closeup of a stub without assistance in picture taking as a leisure activity (right).

pretty cool, and I managed to go back and forth and get back, into the living room then. Yes, without crashing into doors or anything, I tested different turns and I have tried to drive a little closer to Olof my partner (...) He was a little scared, though". (Ruth) Agnes found steering the drone challenging but also exciting, when piloting outside:

> "To get it back that was the hardest part. Because I mean when it starts and I picked it up and then... (but) it was like you were so excited that you forget everything around (...) then it got away, and it went off...."

Both Jennifer and Pamela expressed a desire for additional camera views to improve navigation in narrow indoor spaces.

4.4 Picture taking opportunities

We found that the participants interest in drone use had several connections to accessibility and photography.

4.4.1 Checking inaccessible environments. A few picture taking opportunities were related to practical aspects and accessibility of the surroundings, both indoors and outdoors. Pamela envisioned using the drone to inspect high-mounted cupboards (see figure 2, left image) and look out of windows beyond her reach, and see when service transport has arrived, enhancing her independence in daily tasks. She also saw several outdoor use opportunities:

> "I would use it to see how the vegetation looks in many places that I can't get to (...) I'm very dependent on the ground being flat (due to the wheelchair), so there's a lot I don't see."

"I see more applications outdoors because it would let me assess the accessibility (of places) and much more." She also gave an example (illustrated in Figure 2, image in the centre):

> "You don't want to have to take the wheelchair a long way and then discover that there is a staircase, so you can't get there."

For this reason, more cameras on the drone were desired, preferably to be placed above, under and in front of the drone. Jennifer said that: "It's been a lot of fun playing with it." but also mentioned that it could have a more practical purpose. She described how the drone could be used to check if the roof gutter needed to be cleaned of old leaves:"I could use it to check if the gutters need cleaning here on the house" and explained how she used the drone to see things in her home without physical effort:

> "I was sitting in another room, so I would fly in and see if the candy was on the kitchen table so that I wouldn't have to move myself in there to do that."

Agnes highlighted the need for practice to transition from using a phone to taking photos with the drone: "you have to practice (...) to be able to take pictures (...) you either just look down at the phone or just look at the drone."

4.4.2 Accessible hobby photography practices. Both Pamela and Jennifer discussed using drones for leisure activities like photography to expand their engagement in activities that were difficult to access. Jennifer described how she would like to use a drone to photograph plants, artworks, and animals:

> "If you had a really good camera (on the drone), then it would have been great fun. Then you would be able to photograph flowers without getting out of the wheelchair and you could perhaps take photographs of a bird table or something like that."

However, Jennifer considered that the performance of the drone's camera was much worse than a system camera. Ruth emphasized the opportunity to take photos herself (using her feet) in inaccessible locations, and how this could provide a sense of autonomy (See Figure 2, right image):

> "Then you could fly there and just take a picture of a small stump, or something higher up that you can't reach. That would have been interesting, because then you can take the picture yourself without having to

> ask someone else to help you. Because I can't handle, I can't actually take photos myself, I always have to ask for help."

Ruth thought the drone camera was good enough and useful for photography, and stated that photography with the drone was more fun than with her phone, which she used less for this purpose: "I can't just take out a camera and take pictures in the same way as others can, there will be a little more planning then. She disliked asking people to take photos for her: "many times you want to do it yourself." She also said that: "

> "It's easier with the drone if I want to take a picture myself. Because it is more difficult to explain to a person to go up there (...) and get things exactly as I want them."

However, both Ruth and Pamela mentioned being disturbed by the noise created by the drone and noted that it affected the ability to film or take pictures of animals or even just communicate or talk on the phone. Jennifer also valued the ability to take photos using the drone outdoors but noted that doing so might also present difficulties:"If you are going to take a picture of a flower or a plant or something like that, first of all, there will be wind from it, and then it is so difficult to get close enough."

4.5 Concerns about breakdowns and safety

Pamela specifically mentioned concerns about the drone running out of battery in hard-to-reach places and fears of breakdowns during intimate moments with friends as reasons for not using the drone: "I have a balcony, but I didn't dare use it out there because if it breaks and falls down, then I can't pick it up." Ruth noted similar concerns when she wanted to film her grandson but feared that the drone would be unsafe around children. James pointed out how it was sometimes difficult to foresee what would happen when using the drone: "We live on the third floor. We have a fairly large roof terrace and we thought that yes, a roof terrace should be enough for lifting and such. Then I made the drone fly over the edge of the terrace." When the battery ran out, the drone typically crashed and lost or broke its propellers. This was described as tiresome: "the batteries seemed to run out every now and then so it thumped into the lawn. So, because of that it lost one of the propellers... " A related issue was that if the drone propellers fell off after colliding with objects, they were difficult to locate outdoors: "It's hard to find the propellers because they're black" (Pamela).

4.6 Spaces suitable for flying

Ruth described how flying indoors was impacted by the limited space: "On the second attempt I got stuck in the lamp" (Ruth). Flying the drone outdoors was perceived to be better than flying it indoors because of the lack of obstacles to crash into in open areas. James said that flying outdoors was fairly easy:

> "I probably had a thousand square meters I could fly in (...) I'd fly away from some trees and then fly back and then fly a bit downwards and upwards and so on, it works great."

Agnes preferred an empty field: "because you have to be in such a place that you know, so to speak, preferably in a field where there are not a lot of houses and trees' Weather conditions, including wind, were noted as factors that influenced the ability to practice with and use the drone - as Ruth put it: "I haven't had time to use it that much (because) the weather hasn't allowed me to be out and test often unfortunately. It has been very windy lately".

5 DISCUSSION

This study has examined users' experiences and reflections on drone use to inform our understanding of drone-related challenges and opportunities, particularly those relating to individuals with motor disabilities in hands and arms (and in their legs in some cases). Our findings show several usability and accessibility issues, as well as practical and leisure opportunities for human-drone interaction. Moreover, the analysis highlighted several ways in which drone technology can affect independence. We will now discuss the role that the drone took as an accessibility probe revealing hindering situations and design opportunities, to address able-bodied norms.

5.1 Accessibility and usability in the wild

An earlier study [26] conducted in controlled environments highlighted several important assistive opportunities to better meet the needs of people with diverse cognitive and motor disabilities when operating drones, including adapting the drone's hardware and software and implementing automation. We complement this framework by demonstrating alternative modes of drone interaction, such as maneuvering and controlling a drone with the feet and limited hand functions in indoor and outdoor settings. Furthermore, our findings reveal that usability and accessibility considerations encompass more than just operating and steering the drone; they also involve tasks like unpacking, assembling, and connecting it with other technology. These tasks, described as time-consuming and cumbersome, proved to be bothersome, significantly affecting the overall user experience.

Our participants envisioned using the drone for tasks like checking another room without moving, inspecting high shelves in cupboards, confirming if a taxi had arrived, exploring environments and checking their wheelchair accessibility, and taking photos when unable to hold a camera or phone. The drone was also considered as a useful tool for inspecting whether gutters needed cleaning. This is a situation in which an 'able-bodied' user without limited mobility, strength, or flexibility might not consider using a drone despite the risk of injury by falling. The above applications illustrate how people with reduced mobility can find drone use fun and beneficial, particularly for overcoming environmental obstacles or limitations in existing products and environments. We find that this also relates to an earlier study describing the hacking of everyday tasks with drones performing tasks in alternative ways [60]. Similar to our study they used an exploratory approach, but focused on existing images from social media to investigate people's playful (and social) use of drones in their everyday practices.

Furthermore, the participants' reflections highlighted specific accessibility issues such as problems activating the dual command function on the remote control (pressing two buttons simultaneously), which was difficult for some and impossible for others. Several found it difficult to hold and operate the big and heavy controller, needing to put it down (on the ground or a table) because

of limited or non-existent hand or finger function, lack of strength, or because they operated the drone with their feet.

5.2 Independence and access

5.2.1 Independent picture taking. All participants had an interest in photography, but some were unable to hold a regular smartphone and take a picture independently. However, even in cases where a drone could not be entirely managed without an assisting person (who sometimes would unpack, assemble, charge etc), pictures could still be taken independently. This suggests that drones could increase independence in taking photographs, for example by letting users photograph motifs in nature that are difficult or inaccessible to wheelchair users or letting someone take a picture using their bare feet. Thus, drones could potentially support some hobby photography opportunities such as taking closeups in otherwise inaccessible environments.

5.2.2 Checking out inaccessible environments. Some findings indicate that accessibility needs in the environment will not necessarily be met even when they could be met quite easily, revealing inequalities in society that need to be resolved. For example, some opportunities for drone use, such as checking the accessibility of a site, or checking when service transport has arrived, could be met by making changes to the environment (e.g., adding ramps and elevators) and interiors (e.g., making windows accessible from different heights). This reveals underlying accessibility challenges in for example, interior design, architecture and city planning. This situation somewhat mirrors the challenges in other situations that concerns visually accessing inaccessible environments, such as getting an overview in emergency rescue situations (see e.g. [9, 16, 22]) and checking agricultural harvests [2, 63, 68]. A difference is that current regulations regarding the use of hobby drones in public places can pose challenges when utilizing a drone to explore physical access in new places, and that increased accessibility in society stands as the optimal solution to such matters, benefiting a broader audience.

5.3 Who are hobby drones designed for?

It is commonly known that product experience can be dependent on time, situation, and environment and individual variation in terms of age, body size, strength, and motor skills. The hobby drone used in the study serves as a toy for personal interest and enjoyment. However, its product design, encompassing packaging, assembly process, setup, battery charging, and placement of buttons, falls short in incorporating the fundamentals of user-centered design practice [1] that prioritize accessibility and usability (essential for ensuring an enjoyable experience). Key aspects such as robustness, intuitiveness, and effortless use [52] are notably absent, hindering ease of use and comprehension for users. This influenced the participants' interaction experiences of operating and steering the drone. For example, the drone's design created a requirement for fine motor skills, precision, and good vision due to the placement of the on/off button between the propellers and the difficulty of assembly and disassembly propellers. Additionally, the small text size in the manual and the lack of a Swedish translation necessitated both good vision and language skills when learning how to use the drone. Similarly, the joystick-based remote control was arguably designed to fit large hands better than small ones. This could affect not only people with specific hand or finger impairments or disabilities but also anyone with temporary mobility or cognitive limitations as well as those with gender or age-related variations including children and people with small hands. These are all human variations that reflect a population's similarities and differences, which if addressed through more accessible design could accommodate greater diversity and enable more people to use and enjoy hobby drones.

From a norm-critical perspective, our findings indicate that the current design of the hobby drone (and the remote controller) reflects an able-bodiedness norm [48] that creates a technology displacement favoring a certain 'ideal' drone user and causing disability to others. In this context, it is important to note that physical variation in factors such as strength, endurance, and flexibility can be reduced temporarily and/or permanently and that people's strength and bodily sizes (with hand size being particularly relevant in this case) vary over their lifespan.

5.4 Concerns for technology and independence

Technology used for assistive purposes might not always be adequate or suitable to accommodate accessibility and independence. Based on first-hand experience and reflections, I (Pamela) as an author and a person with impairment and disability needs was somewhat hesitant about describing my experiences of exploring the usability of a hobby drone despite its potential to increase accessibility, comfort, and independence. This is because I fear that such information could be (mis)used to legitimize decisions about future situations in which I might be compelled to accept an inaccessible environment, technology or service because social insurance care agencies, or municipalities can deem an existing solution sufficient to meet a special need. This could motivate social insurance authorities to remove more flexible personal assistance based on the assumption that technological devices such as drones represent acceptable alternative assistive solutions despite being much less flexible than a human assistant, which is a very real concern today [8]. Additionally, even if an assistive device could potentially work in theory it may cause discomfort for the user, as in the case of robotic eating aids that only support one very specific task [42]. This is a critical issue relating to both infrastructure and policy, and one in which people with impairment and disability needs could and should contribute to design research within HDI and HRI, including design practice. Actively including people with different needs makes it possible to quickly identify important opportunities and challenges of both existing and conceptual artifacts.

Moreover, while recognizing the importance of strict ethical procedures and requirements to protect individuals (labeled as ´vulnerable' participants, e.g., [64]), they may also inadvertently serve to exclude individuals and groups from inclusion in research studies. Some researchers may choose not to include vulnerable participants to avoid complex and time-consuming ethical procedures (for example, see [4]), with the risk of creating more distance and estrangement, instead of inclusion and increased knowledge. Disabilities often arise from structural factors, such as environmental or product conditions ([56, 57, 69]) which may not accommodate a

diverse range of individuals. We argue that the 'label' of vulnerable participants can be perceived to reflect a medical model (see e.g. [15, 46]) 'top-down' perspective that categorizes individuals rather than acknowledges diverse needs and expertise. This may perpetuate assumptions about who technology (such as hobby drones) is primarily designed for, and how that person will enjoy them as an leisure activity.

5.5 Strong objectivity

Harding[31] has shown "that science has historically excluded, discouraged, or limited the participation of marginal groups, which undermines the comprehensiveness of scientific inquiry" [30, p.24]. Our work acknowledges the importance of the lived experiences of marginal people such as those with disabilities in research, and of creating opportunities for people with lived experience of impairment and disability to actively participate in research about them [18]. Doing this can not only actively help counteract stereotypical norm perceptions and divisions but also boost and stimulate development and innovations to benefit many.

5.6 Reflection on the research design

Informed by strong objectivity, we challenged notions of value-free objectivity in scientific research and advocated for open and direct participant engagement to mitigate biases and maximize objectivity and to gain valuable insights. In addition, inspired by autoethnography, we argue that without the inclusion of the first author's firsthand perspective from lived experience of impairment and disability informing the analysis, crucial insights regarding challenges and opportunities associated with drones, as well as challenging biases of body norms, along with issues and opportunities for product design, would not have been as readily unveiled. Yet we acknowledge ethical and bias concerns arising from this inclusion, such as the risk that personal narratives, experiences, and perspectives may be overgeneralized and lack generalizability, or that personal interpretations are given undue emphasis, raising concerns about confirmation bias and lack of self-reflection. These potential biases and limitations were mitigated by the critical examination of both authors, whose diverse perspectives helped counterbalance personal biases and broaden the scope of the analysis. Additionally, by including informed consent, and by clearly describing the methodology and data collection techniques, transparency was enhanced.

Furthermore, we acknowledge that presenting findings from a small-scale qualitative study involving only five participants with disabilities may appear limited, it's important to note that this approach is not uncommon in drone research focusing on the experiences of individuals with disabilities (see for example, [3, 5, 6]). Considering the limited nature or absence of studies within HRI and HDI conducted, analyzed, reflected upon, or reported by individuals with lived experiences of disabilities, and the fact that similar studies are often published outside the HRI community, our study, albeit small, may be considered significant as a step towards more inclusive HDI and HRI research. Nonetheless, we emphasize the importance of conducting further studies in collaboration with a larger number of participants with disabilities. This will enable us to compare and evaluate the findings presented in this article more comprehensively.

Moreover, the research set up was negotiated with the participants during the study. For safety reasons and to reduce the risk of the pilot losing control of the drone, all participants were initially asked to have another person as an operator. When participants reacted negatively to this, the research design was changed to omit the request for an additional drone operator, trusting the participants to adapt their use to different circumstances and their own abilities.

In a way the drone functioned as an inclusive design probe, shedding light on several issues that limit and prevent accessibility, equality, and inclusion. This raised questions about existing sources of inequality such as inaccessible environments and how drones could increase or decrease independence. From a design perspective, there is a risk that the study's set up and the handing out of robot technology could provoke only reactive responses to the technology rather than in-depth insights into everyday user needs [42], which is a known risk with other technology probe methods [39]. However, this risk can be argued to have been reduced by the participation of the first author, who helped foster a deeper reflection on findings and add in-depth insights to the dialogue with the second author.

5.7 Implications for norm-creative design

Based on this study, we present implications for future research aimed at supporting norm-creative design within the realms of HRI and HDI.

5.7.1 Exploring mainstream products as accessibility probes. Beyond revealing accessibility hacking and hobby photography opportunities with drones, this study sheds light on many issues affecting users experiences from unpacking to flying (including too short power cords, difficulties of attaching propellers, readability of instructions, bad network, short battery, noise, and weather etc.). Considering alternative controllers (such as a smartphone) and more careful placement of buttons, and avoiding the need for two hands to use the controller, as well as adjusting for gross motor skills could improve the overall ease of use of hobby drones. In addition this could support close-up photography capabilities for people that otherwise need assistance to take pictures. Finally, this study also points towards more general inequalities in society, such as inaccessible environments that need another type of accessible design.

5.7.2 Inclusion of people with different perspectives and needs. Who is a hobby drone user? This question is crucial when exploring use opportunities and challenges. Failure to include individuals with diverse perspectives and varying abilities and needs beyond the normative norm in research and design poses the risk of displacement. This could lead to designs that are skewed towards specific user groups, favoring able-bodied design norms and perpetuating inequality. Such discriminatory practices may result in products that are inaccessible or ill-suited to certain users. Similarly, research findings may not accurately represent the diversity of experiences and perspectives within society, leading to skewed research conclusions and ineffective solutions. Many accessibility and usability

issues have the potential to benefit a broader spectrum of users beyond those with specific disabilities.

5.7.3 Complement research with strong objectivity. Community researchers, and other forms of close collaboration with people who are a minority in a specific context (such as in research), can support strong objectivity in research and offer more nuanced perspectives to avoid stereotyping, especially of individuals who are sometimes interpreted to belong to a vulnerable category of people. Even though this is only a minor study, we find that the combination of a user study and an auto-ethnographic inspired approach deepened our understanding of drone use and related needs. It is possible that the insights and reflections would have been challenging, if not impossible, to obtain without the inclusion of a community researcher with lived experience of disability.

6 CONCLUSION

This in-the-wild study presents how individuals with motor disabilities affecting their arms and hands, including a community researcher, used, experienced, and reflected on mainstream hobby drones in various domestic indoor and outdoor settings. Through their interactions, they provided valuable insights and helped uncover nuanced perspectives on drone use, accessibility, and norms. The methodological approach, where a drone was used as an accessibility probe made it possible to explore potential inclusive design insights and strong objectivity, revealing accessibility opportunities and potential risks from the perspectives of typically marginalized user groups. This supports norm creative viewpoints on drones and highlights potential design exclusion in HDI.

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