Knowledge Work on Airplanes: Challenges, Workarounds, and Design Implications

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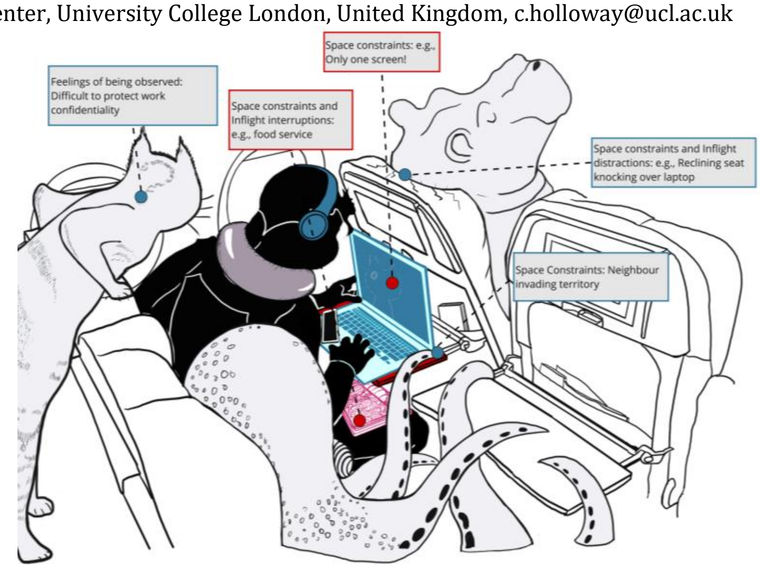

Figure 1: Examples of the identified in-flight challenges when working.

Digital technologies provide significant potential to transform people's lived experiences of working in confined spaces. However, our understanding of the challenges and workarounds of digital knowledge work on long-haul flights is not well documented. To address this research gap, we present the findings of a semi-structured interview study with 21 participants investigating the nuances of working on airplanes (WoA). We identify contradictory attitudes towards WoA and challenges that go beyond spatial limitations, such as well-being issues, feelings of surveillance, and logistic hurdles across the entire journey. Based on this understanding, we discuss design

implications, from portable and functional digital tools to discreet interaction techniques for improving WoA experiences and the potential to extend them to other confined workspaces.

CCS CONCEPTS •Human-centered computing ~Interaction design ~Empirical studies in interaction design

Additional Keywords and Phrases: In-flight Work, Interview, Qualitative Research, Passengers, Transportation, In-transit, Productivity, Airplane, Virtual Workspace

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1 Introduction

Have you ever taken a long-haul flight and planned to catch up with work before landing? Did you achieve your goal? For air travelers whose work life includes constant flying on long-haul flights for conferences or meetings, it is rarely a pleasant journey to sit in economy class while trying to get some work done [9]. The long hours of sitting could lead to musculoskeletal issues such as lower back pain due to enforced poor posture [19], repetitive strain injury, and even deep vein thrombosis [7]. Additionally, the looming threat of sudden reclining of the front seat could potentially cause damage to the laptop screen [44]. As air travel is anticipated for a post-pandemic resurgence, with projections suggesting a rise to 9.4 billion passengers [43], the intersection of these issues with the necessity to work on flights becomes increasingly pertinent. One of the authors who is contributing to those statistics wondered how to design better human-computer interaction (HCI) to support Working on Airplanes (WoA) and other similar resource-constraint settings.

Past research for in-flight experience has predominately focused on two strands. One is enhancing passenger comfort through optimized cabin design and ambient adjustments, focusing on the relationship between human and contextual features [1, 2, 39]. The other is leveraging technology like Extended Reality (XR) Head-mounted Displays (HMDs) to augment the personal work environment within the spatial constraints of an aircraft, capitalizing on the privacy and limitless virtual screens the devices offer [13, 29, 36]. Industry developments, such as the debut of Apple Vision Pro, highlighting the 'travel mode' features for plane rides [37], underscore the growing interest in this area. However, little research has investigated air passengers' current practices and challenges of WoA and these advancements do not fully address the holistic journey of a long-haul traveler, which is not limited to being only in the air. For example, traveling with an HMD device and potential inputs introduces challenges for packing, security clearance, and inflight activities. Such preparation would have implications for the overall design space of using HMD or any other digital tools for WoA.

Recognizing this gap, this paper delves into the real-world practices and challenges of working during long-haul flights, extending the focus beyond the airborne phase to encompass the entire journey. We conducted 21 semi-structured interviews to thoroughly explore the complexities of in-flight work. Our findings highlight five key WoA themes that contribute to passengers' work productivity. Building on these insights, we explore design opportunities for future interaction technologies, aiming to improve the experience of WoA and similar settings where resources and space are limited. This paper offers two principal contributions: enhancing understanding and uncovering the nuanced challenges of WoA across the entire travel journey and laying a foundation for future HCI designs that could transform the way we work in constrained environments.

2 Related Work

This section discusses the prior research in evaluating the requirements for comfortable air travel and improving the in-flight work experience. In doing so, we strive to apply critical findings to the context of our research question – how to improve digital work experience on the plane over long hours and identify the gaps that remain to be answered.

2.1 The Anatomy of Passenger Comfort

The competition among airlines has intensified as the passenger demand for global air traffic remains at a steady growth rate before COVID-19 [45]. To decide which airline to take on cross-continental flights, at least 35% of passengers prefer comfort after flight schedules [3]. Therefore, within the literature, researchers have proposed multiple models from different perspectives to understand the concept and components of passenger comfort and ways to enhance it. The common approach considers comfort as human reactions to psychological, physiological, and physical factors [20].

Ahmadpour et al. [2] surveyed 158 participants and proposed a comfort model of eight comfort themes ("peace of mind", "physical well-being", "proxemics", "pleasure", "satisfaction", "aesthetics", "social" and "association"), linked to twenty-two context features in the aircraft cabin, spreading across five segments including "dynamic", "spatial", "ambient" and "social" environments as well as "passengers' activity". These themes were also validated to apply to discomfort experiences [3]. While this human-context approach emphasizes the importance of contextual conditions, Mastrigt et al. [21] conducted a literature review proposing another conceptual model that dived deep into the seat characteristics (shape, dimensions, and material) and focused on the human-context-seat (product) relationship. Also drawing from literature, Patel and D'Cruz [34] proposed a descriptive model that is human-centric instead, focusing on how personal traits and external contexts shape comfort perceptions.

Despite differing focuses, these models share a holistic perspective, examining the interplay between humans and their environment to understand comfort and discomfort systematically. They intend to work as criteria to guide future air cabin design solutions but are not targeting to improve a specific activity on a long-haul flight. However, comfort is also related to the activities passengers perform [2] and vice versa. Therefore, our paper learns from the previous research methods, aiming to uncover factors that impact in-flight work productivity in addition to comfort.

2.2 The Exploration of Digital Technology for Improving Passenger Experience in Confined Spaces

Recent studies in HCI have ventured beyond the physical structure of the air cabin environment and examined the new interactive technologies to improve the passenger experience for different activities in confined spaces. Based on the comfort model of Ahmadpour et al. [2], Bouwen et al. [5] designed an interactive seat with embedded sensors to control a video game which was found popular among passengers for alleviating physical discomfort, though without significantly reducing musculoskeletal discomfort. This study highlights the potential of integrating sensors into the fixed environment to enhance passenger comfort through exercise in such a confined space over long hours.

2.2.1 XR in Transit –Social Acceptance, Comfort and Virtual Workspace.

Recently, the adoption of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) in enhancing in-flight experiences is gaining traction. For example, Chittaro et al. [8] have shown that VR can make safety briefings more engaging and effective. Williamson et al. [40] first surveyed the social acceptability towards using VR on a flight where the top two issues users have are the need to be aware of surroundings and interruptions from others. Based on this, they developed a VR cinema application and found it could offer passengers a mental escape from the confines of an aircraft.

To further understand the awareness and relationship between users and bystanders, O'Hagan et al. [32] analyzed 14 bystander-VR user interaction scenarios, finding that VR users' awareness depends on the context of the interaction and their previous experiences with bystanders. Research then expanded to survey how AR headsets might infringe on bystanders' privacy [30], uncovering that attitudes toward consent differed based on the AR activity and the nature of the user-bystander relationship, underscoring the need for privacy-enhancing technologies (PETs) to ensure consent and transparency. Building on these insights, O'Hagan et al.[31] discovered that manipulating in-VR audio cues was effective in improving VR users' awareness of bystanders. Moreover, the concept of "Reality Anchors" [4] has been introduced to integrate cues from reality into virtual environments, enhancing user safety, comfort, and social acceptability in transit situations.

Another strand of research focuses on overcoming the ergonomic challenges of confined transit spaces, such as physical and social constraints, through different XR interaction techniques. Studies have found hand-tracking to be a better option than controllers [38] but passengers are concerned about the visibility of mid-air interaction [24]. To improve interaction performance and comfort, Wilson et al. [41] revealed that Linear Gain, one at-a-distance interaction technique replicates the performance and experience of at-home VR well, despite causing significant arm movement and boundary violations. To mitigate that, Medeiros et al. [26] showed the great potential of passive haptic surfaces and perceptual manipulation techniques.

All these insights can be applied to support digital work in XR across various transportation. Grubert et al. [13] proposed that immersive VR work environments redefine productivity parameters in transit. To optimize virtual workspace, various studies have examined the different challenges of working in HMDs considering usability, preferences, and social factors, such as exploring the hybrid use of physical and AR monitors to enhance users' familiarity and trust towards virtual displays [35], proposing a shifted focus to mixed reality (MR) [14, 23] to balance immersion and situational awareness, and finding users' strong preference for vertical virtual display layout for productivity [27]. Additionally, to understand the affordances of different transport modes, Medeiros et al [25] found that passengers often align virtual displays with the physical environment and use them as shields from others in cars, trains, subways, and planes. For air travel, McGill et al. [22] adjusted mapping between gaze angle and display positions to improve user comfort in viewing wide virtual displays. In automotive settings, Li et al. [18] interviewed passengers, seeking to refine VR productivity in rear-seat environments through intuitive UI design.

Despite these advancements and research interests, limited research has analyzed the current practices passengers have when conducting knowledge work in resource-constrained settings like long-haul flights. This paper aims to bridge this gap by conducting a thorough examination of the prevailing issues in WoA. It aims to dissect how interaction design can effectively address these challenges and the implications this holds for developing advanced digital technologies like VR and MR for virtual workspaces.

3 Understanding the Context and Needs of WoA

To probe deep into user experience, we conducted semi-structured interviews to learn how air passengers work on a long-haul flight and identify critical challenges that impact a productive and comfortable experience of WoA. We address the following two main research questions in this study:

RQ1: What are the challenges of WoA?

RQ2: How do these challenges inform user requirements for interaction design for WoA?

3.1 Interview Participants

21 participants (9 men and 12 women) were recruited primarily via direct emails and social media sites like Twitter and LinkedIn. All participants worked for companies with international presence, requiring them to take 10+ hour business flights at least twice a year. Their ages spanned from 18 to 60, broken down as follows: four aged 18-25, eight aged 26-30, four aged 31-35, two aged 36-40, one aged 41-45, and two aged 51-60. While two participants regularly traveled in business or first class, the remainder flew economy. Ethnically, 11 identified as white, nine as Asian, and one as mixed-race. The majority resided in the UK during the study, with exceptions being one each in Norway and Australia.

3.2 Interview Procedure

Ahead of the interviews, each participant was provided with an information sheet and required to fill out an online consent form. This research has ethical approval from [anonymized institution] to conduct these studies. The online interview study was conducted via Microsoft Teams. The average length of the interviews was 28 minutes long.

The interview questions were designed to follow the timeline of taking a flight, encompassing three key areas: (1) Work routine: What types of digital work do people perform, and how do they prepare for WoA? (2) In-flight challenges: What are the main problems people have when WoA? (3) Work strategies: How do passengers maximize in-flight comfort and productivity?

3.3 Data Analysis

We used thematic analysis [6] to code participants' transcripts through three stages. In stage one, interviews were transcribed and coded by using the bottom-up approach. As the coding progressed, related codes were then gradually evolved and refined. In stage two, guided by the primary areas designed in the interviews, the codes were formed into three broad groups, which are 1) benefits, 2) challenges of WoA, and 3) current strategies to maximize productivity. In stage three, through affinity mapping, clear relationships between codes surfaced and coalesced into five key themes for WoA. The supporting quotes from the participants were also fed back to each theme for validation.

3.4 Findings

In this section, we introduce the five identified themes (Figure 1), first by describing the perceived challenges that impede passengers' work productivity on long-haul flights and then presenting participants' attitudes and workarounds for WoA. In doing so, we aim to identify design opportunities to support WoA in Discussion.

3.4.1 The Spatial Constraints.

Unsurprisingly, spatial constraints represent a significant impediment to WoA, not only in the case of economy seats but also intersect with various challenges ranging from pre-flight preparations (e.g., packing and navigating security protocols), to seat choice and inflight activities (e.g., cabin space limits the number of items that can be brought onboard). This impairs participants' usual working habits as one highlighted: '*To format slides and stuff it's easier to use a mouse. It's quicker but I can't. there's no space...* '. This demonstrated how the lack of space restricts the needed functionalities and preferred tools for office work, which makes the actions and tasks harder to achieve.

The constraints extend to the use of devices, including limiting the laptop from fully opening due to the angle of the front-back seat or using smaller devices with no ergonomic support (e.g., tablet stand). Furthermore, due to limited space, personal space might be diminished when interacting with devices (e.g., the laptop ranges into the space of neighbors). The compact environment also heightens the risk of device damage, from spilled drinks or a suddenly reclined front seat. These findings echo the benefits of using HMDs to work (e.g. limited virtual displays) [13, 22] but they are not immune to the challenges of spatial constraints. Issues related to their storage, risk of damage during the flight, and the need for input methods that are easy and familiar to users persist. These concerns all lead to the critical user need for space which opens the design space not only in the interaction design of using HMDs to work but also calls for other innovative solutions that address the multifaceted challenges posed by spatial limitations.

3.4.2 Inflight Interruptions, and Distractions.

The dynamic and often disruptive nature of the in-flight environment leads to inevitable interruptions and distractions. For example, during turbulence, periodic in-flight services, or when neighbors request to leave seats, passengers must pause working and arrange their devices to make room. What makes it more challenging is standing up from one's seat might leave wires of all needed gadgets and chargers trailing down everywhere, cluttering the small space more. One participant elaborated *"It's very annoying when I'm working, and food comes, and I'm like, where do I have my laptop now...then the problem is the person doesn't come to pick up the food. So, I can't work."* Such interruptions coupled with the space constraints commonly disrupt participants' workflow. However, notably, on the contrary, a few participants consider mealtime as a natural break.

Moreover, the logistical aspects of the cabin environment pose additional challenges to WoA. Many airlines have only one power outlet which varies by country, or only one USB port. This not only complicates packing – necessitating items like power banks – but also impacts productivity when devices run out of power. Furthermore, several distractions, such as elevated noise in the cabin, other passengers' behavior, and inflight announcements, contribute to more challenges. Three participants suggested a dedicated work zone in economy class which mirrors the comments from two participants who fly business classes. Both pointed out that the positive ambiance in business class usually motivates them because most travelers work during the flight. These proposed ideas highlight the need to balance between motivating and quiet working environment and the awareness of surroundings and flight services.

3.4.3 Feelings of Being Observed.

Many participants voiced the discomfort of feeling being observed when WoA. First, the spatial constraints lead to privacy concerns especially when participants work with confidential information in proximity to strangers. One participant added, *"You can have the privacy screens, which is maybe that's okay for the person next to you, but not for the person behind"*. In addition, many participants mentioned that when lights are dimmed, the illumination from screens and keyboard sounds can make individuals feel self-conscious, worrying about bothering other passengers and fostering feelings of being 'watched' or 'listened to' at the same time. This shows whether to simply incorporate sound-dampening materials into keyboards or develop VR or MR systems to support WoA, researchers and designers should consider how to alleviate concerns over disturbing others and help users foster a secluded and less conspicuous workspace.

3.4.4 Wellbeing Issues.

Overall, participants indicated several well-being issues lowering the productivity on board: Sitting in a confined uncomfortable space over long hours can cause physical (e.g., back pain, wrist pain from the awkward table height) and mental distress. Participants mentioned the feeling of being trapped as well as the potential risk of experiencing motion sickness due to turbulence. Environmental factors, such as low temperature, food, and cabin smell, coupled with having a reduced private space can intensify these feelings. All these well-being issues adversely affect people's ability to concentrate. To counter these effects, participants make additional preparations, like bringing a travel pillow or blanket. However, the challenges of such strategies are that these items become an extra carry-on, cluttering the space, and are at the risk of being lost in this mobile setting. Taking into account participants' feelings about being observed, researchers and designers should explore how to tackle air passengers' well-being issues both physically and mentally for a comfortable WoA experience.

3.4.5 Attitudes and Strategies towards WoA.

The above-discussed challenges naturally make participants find it difficult to WoA and many would only work when they absolutely must. However, some participants view long-haul flights as an ideal place to work without distractions due to the disconnected internet "*Actually being off the grid can make me more concentrated or focused on doing something*". Further, flying across time zones can enhance a feeling of extended productivity.

To take advantage of long hours and counter the challenges, participants adopted rigorous routines and multiple strategies including pre-flight preparation like downloading or printing essential documents. During take-off when passengers are not allowed to use any digital device, they might make a to-do list and set clear goals. When choosing tasks for WoA, they often prefer the ones that demand less cognitive effort such as organizing files. To stay focused, most participants use noise-canceling headphones not only to block out noise but also to signal a "work mode".

To stay productive, some participants favor window seats for the added space and view, consciously consuming less liquid to limit restroom visits and thus minimize disturbances to neighbors. In contrast, others opt for aisle seats to ensure free movement, increased leg space, and reduced dependence on neighbors. Despite the differences, there is a shared sense of avoiding bothering other people. Also, while some participants layer up to keep warm for working, others deliberately avoid excessive comfort to stay concentrated due to the air cabin atmosphere, which reflected the well-being issues discussed above.

4 Discussion

The key themes identified from the interviews provide rich insights into the challenges users face concerning WoA. These insights carry significant implications for the interaction design of digital devices, software, and the domain of virtual workspaces with HMDs. They also highlight areas for further research to enhance the productivity and well-being of passengers engaged in WoA.

4.1 Productivity Meets Portability

The profound impact of spatial limitations necessitates the development of compact, ergonomic digital tools and devices to support WoA. Considering low table height, charging needs, and risks of damaging the device during travel, future studies could explore the integration of flexible hardware and software solutions, like foldable or rollable technology to accommodate both the limited packing space and confined in-flight environment. In addition, designers can also think about how to repurpose the existing carry-ons such as using smartwatches [33] as controllers for XR and take advantage of cabin physical space to minimize the items taken on board [28].

However, the effectiveness of these solutions also depends on their durability and ease of use [10]. Users should not be burdened with a steep learning curve. Therefore, interaction designs for emerging technologies, such as working in HMDs, must be intuitive, leveraging familiar gestures and controls to ensure immediate productivity. Additionally, offering a range of input methods that users can select based on the task at hand can further enhance functionality and adaptability, ensuring a productive and comfortable WoA experience.

4.2 Discreetness Versus Do Not Disturb.

The desire for discretion emerged as a prominent theme in our interviews, with participants expressing a keen awareness of their surroundings when WoA. This sensitivity to the social environment underscores the need for subtle, unobtrusive interaction designs, particularly for novel technologies. Aligning with Medeiros et al's [24] findings, this highlights users' concerns about the visibility of mid-air interaction with HMDs in transportation. Designers can consider creating hand gestures that require minimum movements mid-air or alternative input methods that attract minimum attention preserving the user's sense of privacy and discretion.

However, a challenge arises: how can users signal their engagement in work to avoid getting interrupted without compromising discretion? For example, participants' divergent views on getting interrupted by cabin service suggest a design opportunity to offer personalized settings in digital tools that allow users to schedule work sessions to align with the in-flight service schedule. Further studies might investigate the balance between privacy and visibility, especially in the context of using HMDs and other immersive technologies.

4.3 Support for Wellbeing and Productivity

Addressing well-being concerns in the context of WoA extends beyond ensuring physical comfort; it also encompasses fostering mental health and productivity. Given the array of distractions in the cabin environment, from visual to olfactory, there's a significant opportunity for designing comprehensive digital tools that cater to these multifaceted needs.

This could include software that promotes healthy work habits, like reminding users to take breaks or do in-seat exercises tailored for users' environment, like the inflight setting. Furthermore, participants' rigid work routine and purposely selection of tasks provide opportunities to consider a smart system to help passengers organize and design in-flight task flow, or intuitive and adaptive interfaces that learn a user's work patterns to suggest different tasks considering passengers' mental load over an air travel journey.

Interestingly, the presence of other business professionals or their co-workers often catalyzed our participants, spurring them to remain productive. This provides immense design space in creating virtual workspaces that simulate the presence of co-workers, business settings, or any virtual space of users' choosing, providing an ambient yet non-distracting background. This leads to an interesting exploration of how the role of avatar embodiment (e.g., type [15], characteristics [16], realism [17]) and social XR [11, 12] can motivate productivity or enhance mental well-being [42] when WoA. Future studies can also explore multisensory MR experiences, inclusive of calming olfactory stimuli, which could pave the way for a more comfortable and conducive work environment.

4.4 Limitations but Potentials in Other Contexts

While we conducted in-depth interviews, there are a few limitations of our study. First, participants in this study have homogenous work backgrounds. More diverse work cases might provide further insights. Future research can engage participants from a wider variety of professions such as using 3D modeling, animation, or coding software.

Secondly, the challenges and user needs discussed in this paper were based on the setting of air travel, and naturally, the challenges of other contexts may vary. However, the insights gained from studying WoA have broad applicability across various confined environments. For instance, discreet interaction might be less crucial in small homes, but the principles of designing compact, portable devices are universally beneficial. Wearable technologies that streamline workspace organization or facilitate effortless transitions from working by a home office desk to a living room sofa exemplify this utility. Furthermore, digital devices, designed for the rigors of air travel—security checks, turbulence, etc.—would work well in any mobile workspace. By considering a wide spectrum of confined environments in the design process, researchers and designers can enhance the versatility and adaptability of interaction technologies. This inclusive approach ensures that the solutions developed are not only tailored to the unique demands of air travel but are also transferable and beneficial in other settings where space is limited, be it in small urban apartments, mobile offices, or any other compact, dynamic work environment.

5 Conclusion

As the number of air travelers is projected to rise, the need for efficient, comfortable, and private workspaces in the air becomes increasingly pertinent. Grounded in interviews, this paper investigates the challenges air passengers face when WoA throughout their entire journey and presents five key themes that are related to WoA productivity. Our findings reveal critical insights into spatial constraints, inflight interruptions, well-being issues, and varying attitudes toward WoA. These insights not only contribute to deepening the understanding of the current practices of WoA but also present a wealth of design opportunities for future HCI interaction technologies to enhance the productivity and comfort of working in not only air travel but also across any confined settings. Our findings set the stage for creating versatile and adaptive work environments in a world where mobility and productivity are inextricably linked.

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