Heads Up!: Towards In Situ Photogrammetry Annotations and Augmented Reality Visualizations for Guided Backcountry Skiing

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Figure 1: Backcountry skiing is an activity where a group of skiers scales a mountainside to ski natural slopes outside of managed areas. It requires clear communication between a professional guide and the recreational skiers to stay safe, minimize environmental impact, and remain exciting and enjoyable. Left: A group of skiers on a guided backcountry skiing tour in Norway. Center: Concept for an annotated photogrammetry map of a mountainside slope. The 3D map displays hazards, slow-down zones, and safe stopping zones authored by the guide to communicate safety risks to the recreational skiers. Right: The skiers view the annotations via augmented reality overlays in a heads-up display. In our demo, participants act out the guide-to-skier communication using a web application and a virtual reality setup. Image Source: Edouard de Becker Remy (left), Google Imagen 4 (center, right) with custom annotations.

Abstract

Backcountry skiing is an activity where a group of skiers navigates challenging environmental conditions to ski outside of managed areas. This activity requires careful monitoring and effective communication around the current weather and terrain conditions to ensure skier safety. We aim to support and facilitate this communication by providing backcountry guides with a set of *in situ* spatial annotation tools to communicate hazards and appropriate speeds to the ski recreationalists. A guide can use a commercial camera drone to create a photogrammetry-based map of a mountainside, then a tablet application to annotate it with hazards, slow-down zones, and safe zones. These annotations are communicated to the skiers via visual overlays in augmented reality heads-up displays. We present a prototype consisting of a web application and a virtual reality display that mirrors the guide's and skier's perspectives, enabling participatory interaction design studies in a safe environment.

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CCS Concepts

• **Human-centered computing** → **Interactive systems and tools**.

Keywords

Backcountry skiing, augmented reality, heads-up display, map interfaces, drones, UAVs

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1 Introduction

Backcountry skiing (closely related to *off-piste* skiing, *freeriding*, and *ski mountaineering*) is an activity where a group of skiers scales a mountainside to ski natural slopes outside of managed areas. This often presents inherent dangers, such as uncertain terrain and natural obstacles (Figure 2a).

Navigating these challenges requires clear communication between the guide and skiers to stay safe, minimize environmental impact, and ensure an exciting and enjoyable experience [6]. Technology plays an important role in enabling and augmenting this communication.

Despite recognizing the need to support risk mitigation in backcountry skiing [28], research to facilitate communication in skiing has so far primarily focused on on-piste environments (e.g., around performance or social activities [5, 8, 18]) or recovery from dangers (e.g., in avalanche search and rescue [4, 21, 22]).

We propose a system to prevent harm in hazardous off-piste environments by supporting communication between backcountry skiing guides and recreational skiers regarding safety issues, utilizing *in situ* photogrammetry annotations and visual overlays in augmented reality (AR) heads-up displays (HUDs).

Our system concept leverages technology already carried on many backcountry tours, such as tablet computers and commercial camera drones, and anticipates future technology (AR ski goggles) to address monitoring and communication needs where guides are typically cut off from communication with recreational skiers: after 'dropping into' a slope section. At the same time, the system allows guides to regulate the amount of information communicated to skiers, preserving the sensory experience of the most rewarding aspect of backcountry skiing: the descent [28].

Our prototype implements this concept using a web application and a virtual reality setup displaying a 3D model of a mountainside slope (Figure 4). A participant, acting as a guide, can remotely control a drone to map an environment, and annotate the virtual environment using the web application running on a tablet computer with hazard, slow-down, and safe stopping zones. Annotations can be previewed by the same or another participant in a first-person view using the web application or a head-mounted display (HMD), such as the HTC Vive Focus Vision. The HMD displays the skier's point of view, including the guide's annotations, from a position on the slope. The system can also be used by two participants simultaneously, with one acting as a guide using the web application and the other as a recreational skier wearing the HMD, communicating potential safety concerns via spatial annotations while navigating down the slope.

Our demo aims to provide insights into effective guide-to-recreationalist communication in extreme natural environments. It prepares a later evaluative study with broader implications for communication strategies to prevent harm to recreationalists and the environment in areas such as hiking, climbing, or mountain biking [28].

In summary, we present the following demo:

- A multi-device system, consisting of a tablet computer and an HMD (HTC Vive Focus Vision), that simulates an *in situ* **photogrammetry annotation** and display tool **for guided backcountry skiing**.
- The **tablet** computer displays a 3D map of an off-piste mountainside slope. A user, playing the role of a backcountry guide, can **annotate** this map **with hazards, slow-down, and safe zones** using touch or stylus interaction.
- The **HMD** shows the skier's perspective. A user, playing the role of a recreational skier, can **view** the guide's spatial **annotations as anchored overlays** that direct the skier's attention to hazards, areas where speed should be reduced, and safe stopping zones to meet up with other group members, giving insights into the effectiveness of the annotations.

2 Related Work

We envision a system that includes an AR HUD for safety-related guide-to-recreationalist communication and an *in situ* terrain-mapping-and-annotation system centered around a tablet computer and a commercial camera drone. It applies them to the domain of backcountry skiing. We therefore review how skiing has been examined in human-computer interaction (HCI) research, how HUDs have been applied in outdoor and safety contexts, and how *in situ* terrain mapping and annotation have been applied in mountainside settings.

2.1 Skiing in Human-Computer Interaction

HCI research has primarily aimed to support skiing activities through the lenses of skill assessment and improvement and social communication. It has mainly focused on on-piste and simulator settings. For example, Zhang *et al.* [29] and Tabei *et al.* [23] developed virtual and augmented reality systems for posture training in simulated skiing environments. Similarly, Hoffard *et al.* [13] used a virtual reality setup to improve skiing posture through haptic feedback.

For multi-person communication in skiing contexts, HCI research has primarily aimed at improving social connectedness, for example, through supporting the sharing of location-tagged photos, videos, points of interest, and hazards in managed ski areas [5], or at improving accessibility in skiing through supporting guide-to-skier communications. For example, several works have focused on providing guidance cues to blind skiers, for instance, through haptics [1, 10] or audio feedback [12]. Most recently, Motahar *et al.* [16] investigated guidance in the context of competitive skiers with tetraplegia, finding that collaboration and safety, but also self-efficacy and independence, are core themes in assisted skiing.

Our system builds on these lines of research and applies them to safety-related guide-to-skier communication in unmanaged off-piste environments. Its primary goal is to prevent harm to skiers



(a) 'Skinning up' a mountain



(b) 'Dropping into' a slope

Figure 2: (a) Backcountry skiing presents inherent dangers due to the uncertain terrain, risk of avalanches, and risk of low visibility. It thus requires effective communication among the group members to prevent harm to people and the environment. (b) Before dropping in, the guide communicates with the group of skiers about the potential hazards and offers recommendations about how to approach the next section, commonly via a walkie-talkie. Image Source: Michael Barz, Edouard de Becker Remy

and the environment. Our work can best be viewed as a follow-up to Fedosov *et al.*'s [6, 7] participatory design research where backcountry skiers were observed, interviewed, and co-designed technology to support communication in off-piste contexts, including a concept for an AR ski goggle application to support off-piste safety communication [6].

2.2 Heads-Up Displays in Outdoor and Safety Contexts

HUDs have been shown to be effective in communicating safety-critical information, including through the use of AR features. This has primarily been demonstrated in applications related to assisted driving [9, 25]. HUDs have also been used in the context of outdoor activities and outdoor sports, such as skiing [17, 18] or cycling [11, 14, 24, 30]. These works mainly aim to increase users' awareness of their surroundings, particularly regarding hazards. At the same time, HUD information must avoid diverting the user's attention from the primary activity, a phenomenon known as inattentional blindness [26].

For example, several works have investigated HUDs to improve safety in cycling, with applications ranging from navigation [11] to hazard notifications [24, 30] and safe overtaking [14]. In the context of skiing, research has investigated how skiers' peripheral vision can be augmented with information about skiers coming from behind to prevent on-piste accidents [17, 18] and speculated how it may help inform skiers of potential hazards and safe paths in off-piste contexts [6].

Together, work on HUDs in safety-critical environments has emphasized that the intent to prevent harm through notifications and annotations must be balanced with minimizing the amount of visual information displayed to the user to limit their overall cognitive load and excessive diversion of attention.

2.3 In Situ Mountainside Terrain Mapping and Annotation

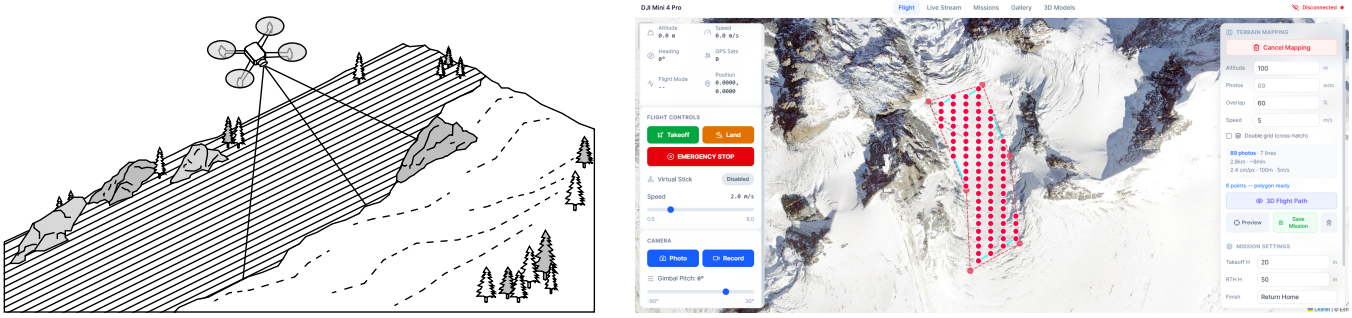
Terrain mapping in the context of on-piste and backcountry skiing has primarily focused on preparatory route planning and *in situ* search-and-rescue situations, generally aiming at collaborative and social contexts. For example, Wiehr *et al.* [27] created a mobile AR system to visualize and collaboratively annotate a topographical mountainside map with routes for ski, hiking, or climbing trips. Similarly, Fedosov *et al.* [5, 8] developed an AR system to annotate ski resort maps with location-anchored content, such as photos, routes, or hazard markers.

In the context of backcountry and off-piste mountainside environments, *in situ* terrain mapping and annotation have been used to effectively conduct and communicate during avalanche search-and-rescue missions [21], including using lightweight drones to map surroundings [21] and locate avalanche transceiver devices [22]. These works have emphasized the importance of flexible devices and collaborative features that facilitate and enrich communication while remaining lightweight and durable in the challenging outdoor conditions.

3 System

Backcountry skiing is usually conducted in groups led by a professional guide who plans an appropriate route together with the skiers, inspects the mountain on the walk up (during 'skinning'; Figure 2a), and continuously monitors weather and terrain conditions, as well as group dynamics. During the descent, the guide ensures the safety and enjoyment of the skiers through continuous monitoring and communication (Figure 2b).

We aim to support this guide-to-recreationalist communication through a multi-component system with two output devices operating in three interaction steps: First, a lightweight commercial camera drone maps the mountain terrain (e.g., during ascent or before descent), providing the guide with a photogrammetry-based *in situ* 3D map (Figure 3a). The guide can then use a tablet application to annotate this map with hazards, slow-down, and safe stopping zones to draw the skiers' attention to safety-critical information (Figure 1, center; Figure 4). The skiers receive the guide's annotations via AR HUDs, which display unobtrusive visual highlights. These strive to draw minimal attention while ensuring the delivery of safety-critical information (Figure 1, right).



(a) Mapping of a mountainside.

(b) Drone control center with a mapping mission.

Figure 3: (a) A commercial camera drone flies up to map the terrain and conditions *in situ*. (b) The drone application for terrain mapping. Using the generated 3D map, the guide can annotate hazards, slow-down, and safe stopping zones to communicate to the skiers.

We prototype this envisioned system by implementing a web application displayed on a tablet computer and a virtual reality application displayed on a commercial HMD (HTC Vive Focus Vision). One user, in the role of the guide, can map a mountainside, then view and annotate the resulting 3D model using the tablet computer running the web application. They can make use of a free-to-navigate 3D view, a top-down view of the slope, and a preview of the skier's first-person perspective to set the annotations (Figure 4). Then, a user in the role of a recreational skier can view the annotations through the HMD, looking around and moving freely along the slope as new annotations appear in real time, mimicking the *in situ* annotation-based guide-to-skier communication. We aim to utilize this demo system in participatory interaction design studies to facilitate discussions with experienced guides and skiers regarding the communication of safety-critical information in backcountry contexts.

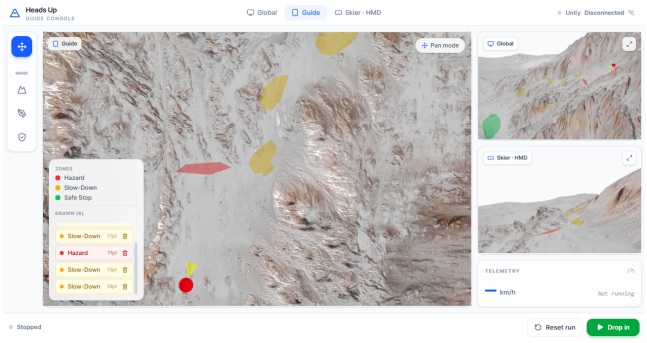


Figure 4: We demonstrate the envisioned multi-device application using a multi-view 3D web application and a commercial head-mounted display (HMD). The user playing the guide can add hazards and draw zones onto a 3D model of a mountainside slope and preview the skier's perspective using the web application or using the HMD.

4 Discussion

Our system is designed to strengthen existing communication patterns between backcountry guides and recreational skiers, particularly concerning safety on unmanaged slopes. The core tension addressed by this design lies between the recreational skier's need for minimal distraction to maximize the sensory enjoyment of the descent and the guide's need for control, monitoring, and ensuring safety. The current system prioritizes the guide's autonomy and control, assuming the guide will provide only the minimum necessary hints to ensure safety while preserving the skier's enjoyment, an approach hinted at as acceptable in related work [6]. However, the principles explored here hold broader implications for other guided and hazardous outdoor activities, such as running, hiking, climbing [28], cycling, or even more extreme environments like diving or cave exploration [15].

A significant challenge moving forward is extending the present prototype from a virtual reality environment to a safe and usable AR system in real-world conditions. We anticipate that the demo will yield fruitful discussions with experienced tour guides and recreationalists in backcountry skiing or related disciplines, such as ski mountaineering. We aim to develop monitoring and communication technologies in close collaboration with guides and skiers, applying human-centered, participatory interaction design methodologies. Our demonstrator will also help investigate how safety features of existing map-based services, such as avalanche terrain hazard maps [19], can be effectively integrated into a backcountry guide's *in situ* decision-making process.

The demo can also facilitate the evaluation of multimodal input technologies [2, 3, 20] based on a combination of, for example, gaze and speech. These may enable more robust and secure communication in critical situations, such as steep slope environments where both hands may be occupied for stabilization (Figure 2a). Furthermore, the system could be extended to incorporate non-safety-related forms of communication common in backcountry skiing, such as mutual encouragement, or to merge with existing practices like recording drone and POV footage, enhancing its integration into the overall experience [6, 8].

5 Conclusion

We propose a multi-device web and virtual reality system for exploring the interaction design of future *in situ* photogrammetry mapping and annotations, supporting guide-to-recreationalist communication in backcountry skiing. The demo aims to stimulate discussion on the effective and safe use of AR and HUD technology in extreme outdoor environments, as well as the development of effective communication tools for addressing safety-related issues within guided outdoor sports activities, particularly in the context of participatory interaction design studies.

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References

[1] Marco Aggravi, Gionata Salvietti, and Domenico Prattichizzo. 2016. Haptic Assistive Bracelets for Blind Skier Guidance. In *Proceedings of the 7th Augmented Human International Conference 2016 (AH '16)*. Association for Computing Machinery, New York, NY, USA, 1–4. doi:10.1145/2875194.2875249

[2] Michael Barz, Omair Shahzad Bhatti, Bengt Lüers, Alexander Prange, and Daniel Sonntag. 2021. Multisensor-Pipeline: A Lightweight, Flexible, and Extensible Framework for Building Multimodal-Multisensor Interfaces. In *Companion Publication of the 2021 International Conference on Multimodal Interaction*. ACM, Montreal QC Canada, 13–18. doi:10.1145/3461615.3485432

[3] Sara-Jane Bittner, Robert Andreas Leist, László Kopácsi, Omair Shahzad Bhatti, Abdulrahman Mohamed Selim, Michael Barz, and Daniel Sonntag. 2025. Interactive Multimodal Photobook Co-Creation in Virtual Reality. In *Companion Proceedings of the 30th International Conference on Intelligent User Interfaces*. ACM, Cagliari Italy, 146–151. doi:10.1145/3708557.3716355

[4] Audrey Desjardins, Carman Neustaedter, Saul Greenberg, and Ron Wakkary. 2014. Collaboration surrounding beacon use during companion avalanche rescue. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing (CSCW '14)*. Association for Computing Machinery, New York, NY, USA, 877–887. doi:10.1145/2531602.2531684

[5] Anton Fedosov, Ivan Elhart, Evangelos Niforatos, Alexander North, and Marc Langheinrich. 2016. SkiAR: Wearable Augmented Reality System for Sharing Personalized Content on Ski Resort Maps. In *Proceedings of the 7th Augmented Human International Conference 2016 (AH '16)*. Association for Computing Machinery, New York, NY, USA, 1–2. doi:10.1145/2875194.2875234

[6] Anton Fedosov and Marc Langheinrich. 2015. From Start to Finish: Understanding Group Sharing Behavior in a Backcountry Skiing Community. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct (MobileHCI '15)*. Association for Computing Machinery, New York, NY, USA, 758–765. doi:10.1145/2786567.2793698

[7] Anton Fedosov, Eleonora Mencarini, Paweł Woźniak, Krisitna Knaving, and Marc Langheinrich. 2016. Towards understanding digital sharing practices in outdoor sports. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct (UbiComp '16)*. Association for Computing Machinery, New York, NY, USA, 861–866. doi:10.1145/2968219.2968537

[8] Anton Fedosov, Evangelos Niforatos, Ivan Elhart, Teseo Schneider, Dmitry Anisimov, and Marc Langheinrich. 2016. Design and evaluation of a wearable AR system for sharing personalized content on ski resort maps. In *Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia (MUM '16)*. Association for Computing Machinery, New York, NY, USA, 141–152. doi:10.1145/3012709.3012721

[9] Thomas Alexander Goodge, Frank Pollick, and Stephen Anthony Brewster. 2024. Can You Hazard a Guess?: Evaluating the Effect of Augmented Reality Cues on Driver Hazard Prediction. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems (CHI '24)*. Association for Computing Machinery, New York, NY, USA, 1–28. doi:10.1145/3613904.3642300

[10] Juan Haladjian, Maximilian Reif, and Bernd Brügge. 2017. VIHapp: a wearable system to support blind skiing. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers (UbiComp '17)*. Association for Computing Machinery, New York, NY, USA, 1033–1037. doi:10.1145/3123024.3124443

[11] Linjia He, Hongyue Wang, Sarah Goodwin, Benjamin Tag, and Don Samitha Elvitigala. 2024. Pedalling into the Future: Towards Enhancing Cycling Experience Using Augmented Reality. In *Companion Publication of the 2024 ACM Designing Interactive Systems Conference (DIS '24 Companion)*. Association for Computing Machinery, New York, NY, USA, 190–194. doi:10.1145/3656156.3663699

[12] Toshihiro Hirano, Yichen Peng, Masaki Kuribayashi, Erwin Wu, Shigeo Morishima, and Hideki Koike. 2025. SlopeNav: A Realtime Wearable Blind Ski Assistance System with Adaptive Path Planning for Simulated Environments. In *Proceedings of the Augmented Humans International Conference 2025 (AHs '25)*. Association for Computing Machinery, New York, NY, USA, 369–380. doi:10.1145/3745900.3746082

[13] Jana Hoffard, Takuto Nakamura, Erwin Wu, and Hideki Koike. 2021. PushToSki - An Indoor Ski Training System Using Haptic Feedback. In *ACM SIGGRAPH 2021 Posters (SIGGRAPH '21)*. Association for Computing Machinery, New York, NY, USA, 1–2. doi:10.1145/3450618.3469158

[14] Yu-Ti Huang. 2025. Safety Sense: Enhancing Urban Cyclists' Perceived Safety during Motorcycle Overtaking through Augmented Reality Warning System. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25)*. Association for Computing Machinery, New York, NY, USA, 1–7. doi:10.1145/3706599.3719280

[15] Eleonora Mencarini and Tommaso Zambon. 2023. Becoming a Speleologist: Design Implications for Coordination in Wild Outdoor Environments. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, 1–12. doi:10.1145/3544548.3581545

[16] Tamanna Motahar, YeonJae Kim, Eden Fisher, and Jason Wiese. 2025. Understanding the Training Experiences of Competitive Skiers with Tetraplegia. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25)*. Association for Computing Machinery, New York, NY, USA, 1–16. doi:10.1145/3706598.3713627

[17] Evangelos Niforatos, Ivan Elhart, Anton Fedosov, and Marc Langheinrich. 2016. s-Helmet: A Ski Helmet for Augmenting Peripheral Perception. In *Proceedings of the 7th Augmented Human International Conference 2016 (AH '16)*. Association for Computing Machinery, New York, NY, USA, 1–2. doi:10.1145/2875194.2875233

[18] Evangelos Niforatos, Anton Fedosov, Ivan Elhart, and Marc Langheinrich. 2017. Augmenting skiers' peripheral perception. In *Proceedings of the 2017 ACM International Symposium on Wearable Computers (ISWC '17)*. Association for Computing Machinery, New York, NY, USA, 114–121. doi:10.1145/3123021.3123052

[19] Outdooractive AG. 2025. *The ATHM*. https://www.outdooractive.com/en/knowledgepage/the-athm/804017798/ Accessed: 2025-11-12.

[20] Sharon Oviatt, Björn Schuller, Philip R. Cohen, Daniel Sonntag, Gerasimos Potamianos, and Antonio Krüger (Eds.). 2019. *The Handbook of Multimodal-Multisensor Interfaces: Language Processing, Software, Commercialization, and Emerging Directions*. Association for Computing Machinery and Morgan & Claypool.

[21] Md Arafatur Rahman, Saiful Azad, A. Taufiq Asyhari, Md Zakirul Alam Bhuiyan, and Khoirul Anwar. 2018. Collab-SAR: A Collaborative Avalanche Search-and-Rescue Missions Exploiting Hostile Alpine Networks. *IEEE Access* 6 (2018), 42094–42107. doi:10.1109/ACCESS.2018.2848366

[22] Jedrzej Stasik and Tomasz Szandala. 2025. An Autonomous Drone for Avalanche Search and Rescue: Integrating ArduPilot and Tracking-Beacon Detection. *IEEE Access* 13 (2025), 130758–130769. doi:10.1109/ACCESS.2025.3585245

[23] Yuki Tabei, Takashi Matsumoto, Yichen Peng, and Hideki Koike. 2025. SkiExARGame: Augmented Reality Exergame for Posture Correction in Alpine Ski. In *Proceedings of the Augmented Humans International Conference 2025 (AHs '25)*. Association for Computing Machinery, New York, NY, USA, 467–469. doi:10.1145/3745900.3747284

[24] Tamara von Sawitzky, Philipp Wintersberger, Thomas Grauschopf, and Andreas Riener. 2024. How to Indicate Multiple Potential Hazards to Cyclists on Smart Glasses? Findings from a Focus Group Discussion with Research Experts and UX Students. In *Adjunct Proceedings of the 16th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '24 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 178–183. doi:10.1145/3641308.3685044

[25] Chao Wang, Derck Chu, and Marieke Martens. 2025. ARive: Assisting Drivers with In-Car Augmented Reality for Risk Zone Detection. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 9, 1 (March 2025), 20:1–20:27. doi:10.1145/3712270

[26] Yuwei Wang, Yimin Wu, Cheng Chen, Bohan Wu, Shu Ma, Duming Wang, Hongting Li, and Zhen Yang. 2022. Inattentional Blindness in Augmented Reality Head-Up Display-Assisted Driving. *International Journal of Human–Computer Interaction* 38, 9 (2022), 837–850. arXiv:https://doi.org/10.1080/10447318.2021.1970434 doi:10.1080/10447318.2021.1970434

[27] Frederik Wiehr, Florian Daiber, Felix Kosmalla, and Antonio Krüger. 2017. ARTopos: augmented reality terrain map visualization for collaborative route planning. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers (UbiComp '17)*. Association for Computing Machinery,

New York, NY, USA, 1047–1050. doi:10.1145/3123024.3124446

[28] Paweł W. Wozniak, Anton Fedosov, Eleonora Mencarini, and Kristina Knaving. 2017. Soil, Rock, and Snow: On Designing for Information Sharing in Outdoor Sports. In *Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17)*. Association for Computing Machinery, New York, NY, USA, 611–623. doi:10.1145/3064663.3064741

[29] Xuan Zhang, Erwin Wu, and Hideki Koike. 2021. Watch-Your-Skiing: Visualizations for VR Skiing using Real-time Body Tracking. In *2021 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*. 387–388. doi:10.1109/ISMAR-Adjunct54149.2021.00088

[30] Guanghan Zhao, Jason Orlosky, Joseph Gabbard, and Kiyoshi Kiyokawa. 2024. HazARdSnap: Gazed-Based Augmentation Delivery for Safe Information Access While Cycling. *IEEE Transactions on Visualization and Computer Graphics* 30, 9 (Sept. 2024), 6378–6389. doi:10.1109/TVCG.2023.3333336