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PEMS: PEOPLES EXPERIENCE OF MOUNTAIN SOUNDSCAPES

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ABSTRACT

This study investigates the role of soundscapes in mountain environments, focusing on their contributions to safety, navigation, and environmental understanding. A survey of 219 participants from 27 countries, primarily experienced mountaineers with varying levels of experience in activities ranging from casual hiking to specialised mountaineering, revealed that natural sounds play a vital role in guiding navigation, enhancing safety, and fostering a deeper emotional connection to the environment. Most participants reported no hearing impairments and rated mountain soundscapes positively (median score of 4/5). Natural auditory cues, such as creaking ice, rockfalls, and shifting snow, were frequently used to assess risks and navigate in low-visibility conditions, while human-made sounds, including traffic noise and overcrowding, were perceived as disruptive and detrimental to the experience. Emotional responses to soundscapes were also significant, with participants reporting feelings of peace, awe, and excitement. Findings highlight the essential role of auditory cues in complementing visual information for navigation and safety in mountain settings. The study advocates further research into soundscape perception and suggests exploring the potential of technology in enhancing sound-based navigation tools to improve safety and environmental interaction in mountain environments.

Keywords: *Soundscapes, Mountain, Perception, Safety, Navigation*

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1. INTRODUCTION

Mountains are not only defined by their towering peaks and vast landscapes but also by their unique and ever-changing soundscapes. The interplay of natural elements—wind, water, wildlife—shapes the auditory environment, offering mountaineers vital cues for navigation, safety, and emotional engagement. While research on soundscapes has largely focused on urban and semi-urban areas, little attention has been given to how sound influences human experiences in mountainous environments. This study aims to fill that gap by exploring the multifaceted role of soundscapes in mountain settings.

Sound serves functional and emotional purposes in the mountains. Auditory cues, such as the creaking of ice, distant rockfalls, or the shifting of snow, provide critical warnings about environmental hazards. These sounds become particularly important in low-visibility conditions, where they complement visual information and aid in navigation. Beyond their practical use, mountain soundscapes shape emotional experiences, evoking feelings of peace, awe, and immersion in nature. However, increasing human activity in mountain regions introduces new auditory challenges, with anthropogenic noise—such as traffic, aircraft, and overcrowding—potentially disrupting natural soundscapes and diminishing their benefits. This study investigates how mountain soundscapes contribute to safety, navigation, and environmental understanding, drawing insights from a survey of 219 participants across 27 countries. By analysing perceptions of natural and human-made sounds, we highlight the significance of auditory information in mountaineering and the broader implications for soundscape ecology. Furthermore, we explore the potential for technological advancements to enhance auditory awareness in outdoor environments. Understanding these dynamics is essential for improving safety and navigation and fostering a deeper appreciation of mountain soundscapes and their role in environmental conservation.





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2. BACKGROUND

Southworth and Schafer describe soundscapes as the acoustic environment perceived or experienced by individuals [1, 2]. In mountain environments, soundscapes include natural elements such as wind, water, and wildlife, alongside human-induced noises like traffic and overcrowding. They provide sensory enrichment and play key roles in safety, navigation, and emotional engagement with the environment. Their significance is heightened in increasingly urbanised and human-influenced landscapes.

Soundscape research has largely focused on urban and semi-urban areas, examining effects on stress, well-being, and spatial cognition [3]. Studies show that natural sounds in urban parks improve psycho-physiological health [4], emotional well-being [5] and reduce stress [6]. However, mountainous environments remain underexplored. Research indicates auditory stimuli enhance landscape appreciation, with Carles et al. [7] showing natural sounds improve perceptions of outdoor spaces, while anthropogenic noise disrupts. Similarly, Irvine et al. [8] highlight soundscapes as integral to environmental perception, linking auditory and visual stimuli to a deeper sense of place. In mountain environments, soundscapes serve both functional and emotional roles. They provide crucial cues for navigation, especially in low visibility, and alert individuals to hazards such as avalanches or rockfalls. Pijanowski et al. highlighted their ecological role in orienting individuals within dynamic landscapes [9]. Sound also enhances group safety, as human voices aid communication in challenging conditions [10]. Natural soundscapes influence emotions and well-being, reducing stress, enhancing relaxation, and improving mood. Research highlights the therapeutic effects of nature sounds [11], their role in fostering a sense of place and emotional stability [12], and their contribution to psychological restoration and stress reduction [13].

Anthropogenic sounds threaten the integrity of mountain soundscapes. They can mask natural auditory cues, impairing safety and environmental awareness [14]. Overcrowding and tourism further reduce the tranquillity of natural settings [15]. The variability of mountain soundscapes complicates their study, as seasonal changes shape distinct acoustic environments, from spring birdsong to autumn wildlife activity and winter storms [16].

Advances in soundscape ecology provide tools to understand these interactions. Early frameworks have evolved to include ecological and cultural dimensions [17]. Preserving natural acoustic environments is increas-

ingly vital amid growing anthropogenic pressures. Recent innovations, including bioacoustics monitoring [18, 19], soundscape mapping [20], and AI [21], offer new ways to explore soundscapes in mountain environments.

Despite advancements, gaps remain. Research rarely explores how individuals with sensory impairments perceive and use outdoor soundscapes. Similarly, the long-term impacts of climate change and biodiversity loss on mountain soundscapes are not well understood. This study examines soundscapes' contributions to safety, navigation, and environmental understanding through a survey of diverse mountain users.

3. METHOD

We conducted an online survey via the NOVI portal to examine mountaineers' sonic experiences. The survey available in our repository [22]. Data were anonymous, requiring no further anonymisation before Thematic Analysis.

Participants were recruited through social media, forums, email lists, and the authors' contacts. They received no compensation. Eligibility required ages 18–70 (per university ethics guidelines) and frequent mountain visits. We collected 219 responses from 27 countries. Participants had a median age of 51 (STD: 14.01). Of these, 60% (131) were male, 39% (83) female, and 1% (3) non-binary. Hearing loss was reported as none 88% (192), mild 8% (17), or moderate 4% (8). Additionally, 17% (38) were audio professionals. Hiking, hill walking, and mountain walking were the most popular activities, each with over 180 participants and an average experience score of 3.6 on a 5-point scale. Their accessibility supports broad participation. Photography was also common (140 participants) but had a lower average experience level (2.3). Niche activities like mountaineering and ice climbing attracted fewer participants yet showed higher experience levels, reflecting their specialised nature. Textual responses highlighted additional pursuits such as wild camping, orienteering, and professional bird surveying, reflecting diverse motivations from adventure to technical challenges and connection with nature.

4. RESULTS

This section presents results from the Thematic Analysis. Raw survey data are available in our repository [22]. Themes are detailed in subsections, labelled Tx, where T represents the theme and x its number.





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Participants described soundscapes as the sounds of an environment that evoke place, identity, and emotional connection, with natural elements like wind, water, and wildlife central. In mountain settings, soundscapes enhance connection to nature, serenity, and navigation while contributing to safety and environmental awareness. Tranquillity, diversity, and immersion were viewed positively, whereas human-made noise, overcrowding, and biodiversity loss were seen negatively. Sounds aid navigation in poor visibility and signal risks such as rockfalls and unstable snow. Emotional responses vary with weather, season, and location, underscoring soundscapes' dynamic role in mountain experiences.

4.1 What does the term soundscape mean?

Participants offered varied perspectives on soundscapes, often describing it as the collective sounds of an environment. P1 defined it as "a group of sounds that collectively evoke a specific environment or setting," while P7 described it as "all the different sounds I can hear." P21 noted its layered nature, calling it "the environment of sound around me, including the interplay of all the different sounds I hear." Others emphasised its role in shaping a place's auditory identity. P35 likened it to "the sound version of landscape; a wide, encompassing or background set of sounds which form an impression of a place," P44 described it as, "the sounds that combine to create the unique sound of the landscape or habitat you're present in." Some associated soundscapes with natural sounds, such as P50, who mentioned "the sounds often heard from nature, e.g., wind and animals in those environments," and P63, who described "a wonderful view filled with rivers, lakes, and forests accompanied by many different sounds of nature." A few were unfamiliar with the term, with P11 stating, "I don't know," and P17 adding, "Not aware of the term." Others saw soundscapes as artistic or musical, such as P85, who described it as "a 'landscape' of music, a large body of available sound to dial into specific parts or hear as a whole."

4.2 Soundscape contributions to mountain experiences

Participant responses highlight six key themes in how soundscapes enhance mountain experiences. A central theme was connection to nature, with natural sounds like flowing streams and wind deepening participants' bond with the environment. P143 captured this holistic sensory engagement, stating, "Everything - views, kinetic experi-

ence, sounds, the wind on my face", capturing the holistic sensory engagement.

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Auditory and visual stimuli were closely linked in participants' aesthetic appreciation, with scenic views enhancing soundscape experiences. P24 captured this integration: "Mountain landscapes... the varied forms of life, be it geological forms to living ecosystems".

Weather was a key factor, shaping the weather and conditions theme. P3 captured its impact: "Weather plays a massive part of the mountain experience and often dictates the mood and overall experience"

Finally, the other category captured unique personal reflections, such as P133's: "Being in nature, exploring, being active" (P133). P199 added, "Everything from journey planning, equipment, packing, to execution - achievement of an objective".

4.3 Mountain Soundscapes rating

On a scale from 1 (unpleasant) to 5 (pleasant), participants rated mountain soundscapes a median of 4 (STD 1.5). Many appreciated natural sounds like birdsong, wind, running water, rustling leaves, and animal calls (17 mentions). These elements foster peace and tranquillity, offering a calming effect in the absence of human-made noise (16 mentions). Their ever-changing, unique nature enhances the auditory experience, making each encounter distinct and engaging (12 mentions). The soundscape also deepens the connection to nature (9 mentions) and complements the visual landscape (8 mentions). Its uniqueness, distinct from urban settings, was noted 7 times, while its soothing effects contributed to relaxation and well-being (6 mentions).

Negative aspects of soundscapes included intrusive human-made noises from traffic, aircraft, and chatter (15 mentions). Overcrowding from tourism disrupted serenity (7 mentions), while biodiversity loss, reflected in fewer wildlife sounds and degraded landscapes, was noted 6 times. Sound quality varied with location, weather, and time (6 mentions), and some experienced disappointment when expected quiet was absent, particularly in degraded





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habitats (4 mentions).

Neutral or variable aspects include the context-dependent nature of soundscape appreciation, with ratings influenced by individual situations, locations, or preferences (12 mentions). Additionally, some respondents found the concept challenging to define or rate, reflecting a possible unclear understanding of what constitutes a soundscape (11 mentions).

4.4 Sounds heard in the mountains

The analysis of the datasets reveals meaningful cross-relations, particularly between the frequency and ratings of sounds heard in the mountains. General sounds like wind, birds, and water emerge as the most frequently reported, with a median frequency of 4 (on a scale of 1–5), respectively. These sounds are also among the highest-rated, with birds, water silence and wildlife achieving a median rating of 5. This strong alignment ($r=0.79$) indicates that commonly heard sounds are generally appreciated. Conversely, sounds like traffic and rockfall are among the least reported, with median frequencies of 2 and 1, and lower median ratings of 1 and 3, respectively, highlighting their occasional and disruptive nature.

For "other heard sounds," categories like climbing gear, calls, and crunching snow or ice stand out, with climbing gear being the most frequent (median 1). However, these sounds are less frequently reported and rated than general sounds, reflecting their situational and activity-dependent nature.

4.5 Memory of a mountain soundscape

We asked participants about a memorable soundscape while they were in the mountains. The relationship between place, emotions, time of year, and weather conditions is intricately tied to the sounds participants hear in mountain environments. In high-altitude regions like the Alps and Pyrenees, dramatic sounds such as rockfalls (P9: "location: Italian Alps, under Mont Blanc in 2014" "soundscape: It was a rockfall" "sound: deep rumble of boulders falling", "emotion: excitement and fear"; P17: "location: Chamonix Vallee Blanche. Summer 2019" "Sound: rockfall and echoes", "emotion: became alert, edgy"), thunder (P48: "location: Flame des Pierres, Le Dru, Chamonix, descending after climbing North Face July 1988", "sound: cacophony of intense sounds followed by silence; thunder and sound of rockfall caused by lightning strikes then the silence when the storm moved

far enough away" "emotion: fear, shock and awe followed by relief and peace"), avalanche (P88, "location: the sound of a huge avalanche coming off the Aiguille du Chardonnet", "sound: A big boom!", "emotion: Excitement and fear") and roaring winds evoked awe, fear, and excitement. These auditory cues emphasised the power and unpredictability of nature, intensifying the emotional connection to these imposing landscapes. Wildlife-rich areas, such as the Scottish Highlands, were characterised by distinctive sounds like stags bellowing during the rutting season (P87: "location: Frequently on high tops In Scotland rutting season" "sound: Stags bellows a bit frightening, the noise was echoing of the valley" "emotions: silence- peace connection with the earth/ universe") or bird calls, which evoked feelings of wonder and connection to the vibrant ecological systems. In open fells and plateaus, like the Lake District, calming sounds such as whistling winds or the quiet rustling of vegetation created a sense of peace and introspection, offering moments of reflection in the vastness (P36: "location: Helvellyn, Lake District, May 2023, afternoon", "sound: Notable Sound: Wind, insects", "emotion: Calmness, peace, satisfaction, quiet joy").

The time of year further shaped these experiences. In autumn, sounds of wildlife activity, particularly stags bellowing, combined with crisp weather to inspire awe and excitement. Spring introduced a mix of dynamic auditory elements, such as bird calls and shifting winds, fostering feelings of surprise and renewal. Winter storms heightened the emotional intensity with thunder, howling winds, and the rumble of falling snow or ice, eliciting fear and adrenaline. Summer's auditory palette, while less intense, includes softer sounds like gentle breezes or distant echoes, evoking tranquillity.

Weather conditions play a crucial role; stormy weather amplifies dramatic, awe-inspiring sounds, while calm days enhance the meditative quality of subtle and serene auditory cues, creating a deeply contextual emotional experience.

4.6 Soundscape's contribution to navigation

Overall, 169/219 participants indicated that the soundscape contributed to navigation, while 50 participants indicated that the soundscape did not contribute.

Natural Sounds for Navigation. Participants frequently relied on natural sounds like water, wind, and echoes to navigate. P91 stated, "Water/streams; nearby roads," while P190 highlighted "Wind, thunder, rock





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falling, and rain” as key auditory cues. These sounds are particularly valuable in conditions of poor visibility. P3 shared, “Very rarely, usually in poor visibility when hearing echoes or voices helps.” Similarly, P72 explained, “The sound of water matches my map, traffic gives directional hints.” These natural cues allow individuals to confirm their location and orient themselves effectively.

Anthropogenic Sounds. Human-made sounds also play a significant role in navigation. P152 shared, “Hearing voices helped us locate a nearby group in poor visibility,” emphasising how anthropogenic sounds act as crucial orientation aids. Similarly, P37 noted “Traffic noise after nightfall” as a reliable cue for locating roads or urban areas. These auditory markers are particularly helpful in disorienting environments.

Real-Life Scenarios. Specific instances vividly demonstrated how sound can support navigation. P48 recounted, “A misty Duddon Valley fell race, trying to find a checkpoint by following the river sound.” Similarly, P152 described navigating thick fog: “I couldn’t see a river as it was very foggy, but listening to its sound reassured me that I was on the correct path.” At high altitudes, P179 relied on environmental sounds, stating, “The wind and its direction, the location of moving water, provided spatial orientation.” These examples highlight the practical and life-saving role of sound in navigation.

Sound Enhancing Awareness. Beyond practical use, sound enhances environmental awareness. P120 described, “A change in the sonic atmosphere makes you take notice of your surroundings.” This insight underscores how sound can foster mindfulness, encouraging a deeper connection to the environment.

Participants who felt that sound does not contribute to navigation often cited reliance on visual aids such as maps, compasses, and GPS, emphasizing their preference for visual over auditory cues. For example, P192 stated, “I navigate with a map, compass, using my eyes to look at the landscape,” and P215 shared, “I’m not confident navigating and stick to visual aids like map, compass, GPS, written notes rather than sounds.” Many found sound unreliable or inconsistent, noting environmental factors like wind direction being unpredictable. As P144 explained, “Wind direction is subject to change so wouldn’t rely on that.” Familiarity with well-defined routes also diminished the need for sound, with P150 saying, “There are usually treks that we follow.” Others, such as P160, admitted, “It’s not something I’ve ever considered linking to navigation.” This highlights the varying relevance of auditory information depending on habits and terrain.

4.7 Soundscape’s contribution to safety

Sound plays a critical role in risk assessment for many participants, offering valuable cues about potential dangers. When answering questions about soundscape contribution to safety, 189 participants stated that sound contributed to risk assessment in the mountains, while 30 said no.

Wind was the most frequently mentioned sound, cited by 10 participants. P4 explained, “When the sounds were louder or prolonged, I was aware that the risk was higher,” emphasising how auditory intensity can inherently signal increased danger. In relation to wind, sound is an important indicator to evaluate potential hazards in the route ahead. To this regard, P22 said, “In Patagonia we were on the sheltered side of a mountain but could hear the wind like a jet engine around the summit”.

Creaking and groaning sounds in snow or ice were highlighted as critical indicators of instability, with P5 noting, “Listening to creaking or groaning snowbanks would make me steer clear”. P26 said that the “wumph!” can give information about potential “avalanche and snow layer collapse” and “obvious layering in snow cover”. P31 adds “Winter mountaineering, listening for the sound of certain hollow or dense patches of snow to know where to walk preferably”.

Environmental sounds, such as avalanches, rockfalls, and water, also played a prominent role. P6 recounted, “The noise of the stream suggested that it was not passable,” demonstrating how natural sounds can immediately influence decision-making. Others used sound to identify objective dangers, such as rockfalls during warm summers. P7 shared, “I could hear lots of rockfalls and icefalls in the French Alps, making me more cautious in dangerous locations.”

For some, sound facilitated communication and hazard awareness within groups. P1 observed, “Ease of communication with group members and the sound of avalanche or rockfall indicate objective danger,” highlighting the collective role of sound in ensuring safety. However, 30 participants stated that sound does not contribute to their risk assessment. P2 explained, “Stonefall, thunder, snow settling, and avalanches are insufficiently distinctive to guide decisions”.

4.8 Soundscape’s contribution to understanding your surroundings

A total of 193 participants (88%) stated that sound does contribute to understanding the surroundings, and 26 indicated that sound does not contribute to it.





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The most prominent theme was water and natural sounds, frequently mentioned as critical auditory markers. Participants cited rivers, waterfalls, and streams as essential for navigation and environmental awareness. For instance, P219 explained how "hearing water, from trickling streams to roaring falls," prompts reflections on the hydrological cycle and erosive processes shaping the landscape. Similarly, P111 shared how "the sounds of water moving" aided in locating themselves in challenging terrains.

Another significant theme was danger awareness, where sounds like avalanches, rockfall, and strong winds provided critical warnings. P100 described how these sounds "heighten awareness of dangers and risks," while P203 recalled how "strong winds on Cairngorm reinforced the wild and potentially dangerous nature of the area." Participants also discussed navigation and orientation, relying on auditory echoes, flowing water, and even voices to locate paths. P205 recounted using "the sound of wind to estimate proximity to a ridge during a night summit."

Beyond practical uses, sound fosters connection to the natural environment. Six participants highlighted silence and ambient sounds as sources of peace and deeper appreciation. P169 reflected on "Arctic silence" and its ability to convey fragility, stillness, and vastness. Likewise, P141 described a hike in the Cairngorms (Scotland), where the absence of sound amplified the experience of solitude.

Of the 26 participants who indicated that sound does not contribute to their understanding of surroundings, several provided specific explanations. A common reason was a preference for visual cues over auditory ones, as noted by P4, who stated, "I use visual cues more than anything else." Others, such as P56, described sound as supplementary to other sensory inputs like sight, touch, and smell. Environmental factors also influenced perceptions; P67 highlighted differences in wind and bird sounds depending on elevation. P30, found auditory cues ambiguous, noting that "a flowing river being covered by grass can be hard to locate as the sound is all around." P165 admitted to limited use or awareness of soundscapes, stating: "I do not remember ever using the soundscape to gain understanding of the surroundings."

5. DISCUSSION

The results of this study offer a nuanced understanding of how soundscapes can contribute to participants' experiences in mountain environments, particularly in the areas of navigation, safety, and understanding their surroundings. Participants provided diverse definitions of

"soundscape," reflecting its multifaceted nature. Most commonly, soundscapes were described as the collective auditory characteristics of a place, combining natural and human-made sounds to form a unique auditory identity. This definition underscores the interplay between environmental and contextual factors in shaping participants' auditory experiences. Participants' ratings of mountain soundscapes were overwhelmingly positive, with a median score of 4 on a 5-point scale. They frequently cited the calming, immersive qualities of natural sounds like birdsong, wind, and running water, which were valued for their contribution to relaxation and well-being. Conversely, human-made noises, such as traffic or overcrowding, were identified as detracting from the overall experience, highlighting the tension between natural and anthropogenic soundscapes in these environments.

Soundscapes can play a critical role in mountain safety by alerting individuals to environmental risks. Natural sounds such as creaking ice, groaning snow, and rockfalls serve as auditory warnings, enabling participants to identify potential hazards and adjust their behaviour accordingly. These sounds are especially important in high-risk scenarios, such as navigating unstable snowfields or avoiding rockfall-prone areas. Participants also emphasised the importance of wind sounds, noting how variations in intensity or direction could indicate heightened risks, such as approaching storms or exposure on ridges.

Group communication was another safety-enhancing aspect of soundscapes. The ability to hear teammates' voices in poor visibility or during emergencies facilitated coordination and collective awareness of hazards. However, some participants expressed scepticism about the reliability of auditory information, citing environmental factors like wind distortion or indistinct sounds as potential limitations. These findings suggest that while soundscapes are indispensable for safety, they are most effective when used alongside other sensory inputs and tools.

Navigation in mountainous terrain often relies on auditory cues, particularly when visibility is reduced. Participants frequently used natural sounds, such as flowing water or echoes, to orient themselves and confirm their position relative to maps and landmarks. For example, the sound of a river might help pinpoint a trail crossing, while wind direction could guide orientation during a summit attempt. These auditory markers were especially valuable in disorienting conditions like fog, snowstorms, or dense forested areas. Real-world examples highlighted the practical importance of soundscapes in navigation. One participant described following the sound of a river during a





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foggy race, while another relied on wind direction to locate a ridge at night. Anthropogenic sounds, such as traffic noise or distant voices, also served as orientation aids, signalling proximity to roads, settlements, or other groups. However, some participants preferred visual aids, such as maps and compasses, over auditory inputs, underscoring the need for integrating soundscapes with more conventional navigational tools for maximum effectiveness.

Soundscapes can enhance environmental awareness by providing critical information about the surrounding landscape. Natural sounds such as rivers, waterfalls, and bird calls were frequently mentioned as auditory markers that helped participants understand their environment. These sounds often prompted reflections on ecological processes, such as water cycles or wildlife behaviour, fostering a deeper connection to the natural world. Participants also highlighted the role of soundscapes in helping to identify dangers, such as avalanches, rockfalls, or unstable snow, which heightened their situational awareness. Beyond practical applications, soundscapes offered emotional and cognitive benefits, promoting mindfulness and enhancing participants' appreciation of their surroundings. For instance, the silence of remote areas or the subtle rustling of vegetation amplified participants' sense of solitude and connection to the environment.

6. CONCLUSION AND FUTURE WORKS

This study highlights the profound role of soundscapes in shaping experiences in mountain environments, particularly in the realms of navigation, safety, and understanding surroundings. Participants demonstrated a nuanced appreciation for the auditory characteristics of these landscapes, recognising both their practical and emotional significance. Natural sounds, such as flowing water, bird-song, and wind, emerged as critical cues for orientation and personal risk assessment, while human-made noises often detracted from the immersive experience. The findings emphasise the dynamic interplay between auditory and visual inputs, with soundscapes as supplementary and primary tools in specific contexts.

Safety and navigation were key areas where soundscapes proved invaluable. Auditory cues have been declared to identify hazards, orient themselves in low-visibility conditions, and maintain group cohesion. These findings underscore the importance of preserving natural soundscapes as they enhance individual experiences and provide critical information for decision-making in challenging environments. However, the variability in partici-

pants' reliance on soundscapes highlights the need for integrating auditory cues with visual tools to create a more holistic approach to mountain safety and navigation.

We demonstrated the importance of soundscape and its awareness in mountain environments, gaps remain in current research. One key area is the limited understanding of how individuals with varying levels of hearing impairment or sensory preferences perceive and use information gleaned from soundscapes. Future research should explore these differences to identify inclusive strategies for enhancing auditory experiences. Additionally, there is a need for longitudinal studies to assess how changing environmental conditions, such as biodiversity loss or climate change, affect soundscape quality and perception over time. Another opportunity lies in the integration of artificial intelligence (AI) and augmented reality (AR) technologies with soundscape research. For instance, wearable devices that amplify or isolate specific sounds could improve navigation and safety for individuals in challenging environments. Furthermore, the role of soundscapes in fostering ecological awareness and conservation behaviour remains underexplored. Public education initiatives and interactive soundscape experiences could help bridge this gap, encouraging greater appreciation and protection of natural soundscapes. For example, awareness of the impact of green laning and the use of drones. Finally, interdisciplinary approaches that combine ecological [24], psychophysiological [25], and technological perspectives could provide a more comprehensive understanding of soundscapes. By addressing these gaps, future research can enhance the practical and emotional benefits of soundscapes, ensuring their continued value in mountain environments.

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