SHORT-PAPER

The Tussle Between Brain Waves and Hairstyles: A Case Study of Usability Challenges with an Entry-Level EEG Device for Female Participants

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The Tussle Between Brain Waves and Hairstyles: A Case Study of Usability Challenges with an Entry-Level EEG Device for Female Participants

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Abstract

This study investigates the hardware-related usability challenges that arise when using an entry-level Electroencephalography (EEG) device, specifically the Emotiv EPOC+, in user studies involving female participants. We focused on how head size and hair characteristics impact EEG signal quality and conducted a time-controlled training and usability session with five participants. We assessed hair density, texture, and length through self-reports and visual verification, and measured head circumference directly. Our results show that participants with thicker hair and larger head sizes had greater difficulty achieving proper electrode-scalp contact, which increased impedance and reduced signal quality. Additionally, participants with straight hair experienced slippage that compromised headset stability. As an exploratory pilot case study, this work identifies critical inclusivity gaps in current EEG headset design and offers actionable insights for HCI researchers aiming to improve the usability of EEG technologies for diverse female participants.

CCS Concepts

• **Human-centered computing → User studies**; *Usability testing*.

Keywords

EEG, brain-computer interface, user study, usage challenges, female participants

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1 Introduction

Brain-computer interfaces (BCIs) that leverage electroencephalography (EEG) offer considerable promise for enhancing the study of user experiences in human-computer interaction (HCI). However, realizing this potential requires addressing persistent challenges, foremost among them, the reliability of EEG signal acquisition [16]. Achieving consistent, high-quality signals depends heavily on stable and unobstructed electrode-to-scalp contact, which individual physiological attributes can influence. In particular, hair type, head size, and overall comfort significantly affect the usability of EEG systems [23]. While these factors are especially pertinent for female participants, they remain underexplored in HCI research [34, 35], leaving a critical gap in understanding how EEG devices perform across diverse populations.

To shed light on these challenges, in this study, we address the following research questions (RQs):

- RQ1: *How do different hair characteristics (density, texture, length) influence the reliability of electrode-to-scalp contact when using an entry-level EEG device?*
- RQ2: *How does head size influence the fit, comfort, and stability of an entry-level EEG headset for female participants?*
- RQ3: *To what extent does the comfort of wearing an entry-level EEG headset influence female participants' willingness to engage in user studies?*

To investigate these research questions, we conducted an exploratory user study focused on the usability of an entry-level EEG device among female participants. While hair characteristics can affect EEG performance for all users, this study centers on female participants due to the broad variation in women's hair types and styles [5], which introduce unique usability challenges for EEG devices [23]. Despite the relevance of these factors, the HCI literature has paid limited attention to the specific experiences of women in usability contexts [21, 40]. By concentrating on this underrepresented demographic, our study offers new insights into how diverse hair characteristics interact with EEG technologies in real-world HCI applications. We specifically examine entry-level EEG systems specifically the Emotiv EPOC+, because these devices are widely available and frequently used in both academic and applied settings [3, 33, 36, 41]. The EPOC+ in particular has been shown to support usability-focused studies due to its multi-channel setup, compatibility with standard computing platforms, and ease of setup compared to more advanced systems [13, 41, 45].

We measured EEG signals as participants wore the headset configured with a range of common hairstyles, including braids, ponytails, and loose hair. Head circumference was recorded, and participants' comfort levels were assessed during use. preliminary findings revealed several usability challenges that affected EEG-based BCI performance among female participants. These challenges, related to hair type, head size, and comfort, influenced signal reliability and overall device functionality [47]. These early insights emphasize the

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need for an inclusive EEG device design that better accommodates diverse female users. Addressing these usability challenges may increase participation and improve data quality in HCI research. In doing so, this work supports broader efforts to expand the applicability of EEG-based BCIs in domains such as education, healthcare, and interactive technologies [11].

2 Related Work

EEG technology has become increasingly prominent within HCI research [2], yet several longstanding technical limitations continue to constrain its broader application. Prior studies have identified key challenges such as electrical interference, motion artifacts, and signal disruption caused by hair [14, 44, 45]. EEG recordings also remain highly susceptible to variations in scalp and hair conductivity, as well as to head movements, all of which can compromise signal integrity [6]. These issues collectively reduce EEG signal quality and jeopardize the validity of EEG-based BCI findings, particularly in uncontrolled or user-facing environments [24].

Researchers have developed EEG-based BCIs for a wide range of applications, including gaming, emotional state analysis, clinical interventions [46], and virtual reality (VR) applications [12]. These systems differ in technical specifications such as channel count, sampling rates, and noise reduction capabilities [39]. Despite these advancements, existing work has paid limited attention to the usability of EEG technology, particularly from the perspective of female participants [20]. As EEG adoption in HCI expands, this gap presents a growing concern. Much of the current research has focused on signal fidelity and hardware development [35, 45], while overlooking the user-centered challenges that arise during real-world use. Since these challenges can significantly hinder EEG deployment in diverse settings, further investigation into inclusive and user-adaptive EEG design is needed.

Understanding how hair affects EEG signal quality remains critical for the success of EEG-based studies. Some researchers have proposed detailed hair classification systems, such as an eight-group typology based on curliness measurements [25]. In contrast, our study adopts a simplified classification approach based on three practical dimensions: density (thick, medium, fine), texture (curly, wavy, straight), and length (long, medium, short). This framework draws on established categories in dermatology and cosmetology [25], and aligns with the way users commonly describe their own hair. Its simplicity made it appropriate for a pilot usability study that did not require extensive training or instrumentation.

Hairstyles also influence EEG signal quality, especially in usability studies where preserving participants' natural or preferred styles is often important [27]. Hair can act as a physical barrier that introduces electrical resistance and interferes with proper conduction between the scalp and electrodes [18, 44]. In addition, some hairstyles can exacerbate movement artifacts and make it more difficult to maintain consistent electrode-to-scalp contact throughout the recording session [29].

Recent studies with Black participants have shown that thick and textured hair, especially in styles like cornrows and braids, can interfere with EEG recordings [7, 30, 31]. These studies link such hair types to movement artifacts and electrical interference. However, most have focused on clinical or high-end EEG systems [19]. Few have examined how hairstyle and hair type affect signal quality in entry-level devices [19, 45]. They have also rarely considered the impact on female participants from diverse ethnic backgrounds. By focusing on entry-level EEG use among women with a range of hair types, our study builds on this work and addresses a gap in current research.

3 Methodology

3.1 Procedure

The study consisted of two phases: a training session followed by a usability test session, as illustrated in Figure 1. In the training session, participants received an introduction to the EEG headset, including instructions on correct electrode placement and basic operation of the associated software. They also reviewed a brief overview of EEG technology and its typical applications. Participants wore the EEG headset continuously throughout both phases to simulate realistic usage conditions and ensure consistency in data collection.

During the usability test session, participants completed a series of tasks designed to evaluate the EEG headset's ease of use, comfort, and practicality. These tasks included launching the EEG software, adjusting parameters in a 3D brain visualization interface, and training a user profile to stream emotional states from EEG data. After completing the session, participants reported their age, height, and nationality (used as a proxy for ethnicity), and the researcher measured their head circumference in centimeters for later analysis.

Participants then completed a four-item questionnaire designed to assess the usability of the EEG hardware, focusing specifically on setup difficulty and headset comfort. The questionnaire deliberately excluded evaluation of the accompanying software or broader EEG applications to maintain a focused assessment of the physical device. The items included:

(1) How would you describe your hair's density/thickness?
(2) How challenging was it to set up the EEG headset device on a scale from 1-5? (5: very challenging, 1: not challenging)
(3) How likely will you repeat the experiment on a scale from 1-5? (5: very likely, 1: unlikely)
(4) How comfortable was the headset device?

Finally, We recorded the start and end times of each session to assess task duration and setup efficiency. Most participants completed both the training and usability testing phases within five minutes. However, one participant required over ten minutes to complete all tasks, highlighting variability in setup time, potentially due to individual differences in hair characteristics and head size.

During setup, participants adjusted the Emotiv EPOC+ headset to align the electrodes properly with the scalp. The headset consists of semi-rigid sensor arms, each holding a circular electrode that magnetically attaches to predefined fixture points on the device. Although the sensor positions follow a standardized layout, users can replace or reposition the electrodes if needed. The device requires the electrodes to be moistened with saline solution before use to ensure conductivity. A researcher manually hydrated the felt pads at the beginning of each session and rehydrated them when necessary, particularly if extended setup time caused the sensors to dry out or lose contact.

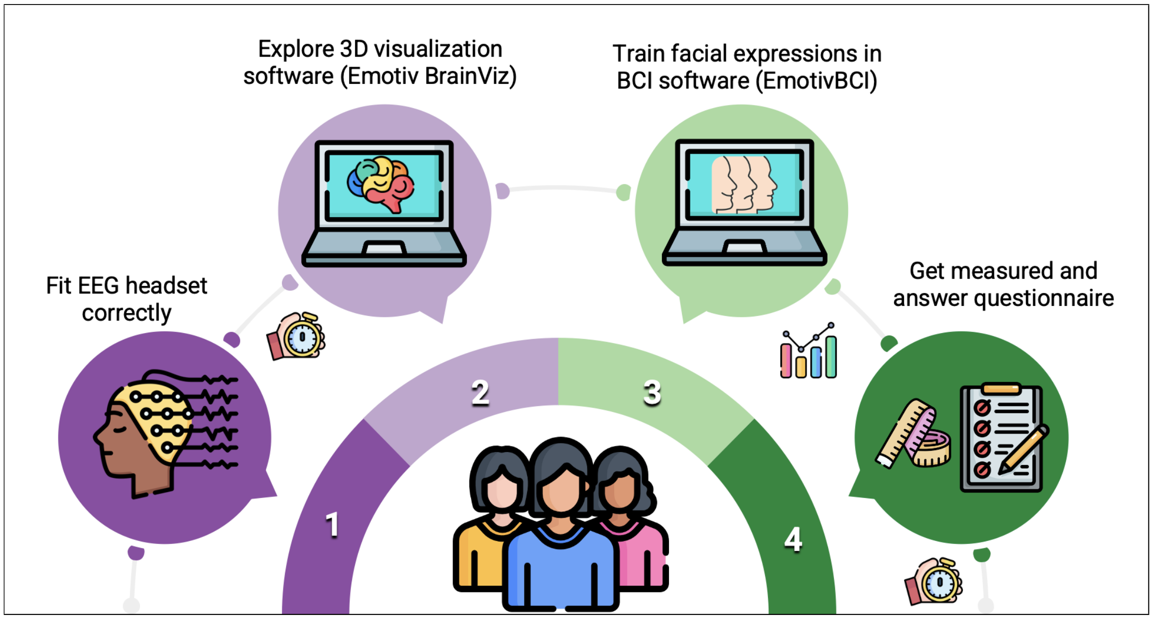

Figure 1: The usability user study procedure employing EEG devices with female participants to assess the impact of hairstyles on the reliability of EEG measurements

This adjustment process varied across participants and was influenced by hair type and head size. Participants with thick, curly, or voluminous hair often needed additional time to reposition electrodes or apply more saline to ensure adequate scalp contact. In several cases, signal degradation was visible through the device interface, prompting either rehydration or headset repositioning. These interactions, along with real-time feedback from the software and participant self-reports, helped inform qualitative assessments of signal stability and overall device usability.

3.2 Apparatus

Entry-level EEG-based brain-computer interfaces (BCIs) aim to be accessible, cost-effective, and user-friendly, making them suitable for non-specialist users and researchers [26]. Unlike high-end clinical EEG systems, which are expensive and require expert setup, consumer-grade devices provide an approachable entry point into EEG technology [28]. Notable examples include the Emotiv EPOC+[1] and the NeuroSky MindWave Mobile 2: Brainwave Starter Kit[2], both of which are commonly used in educational, hobbyist, and exploratory research contexts.

The Emotiv EPOC+ is a wireless EEG headset with multiple electrodes designed to detect electrical brain activity. It supports a wide range of applications, including gaming, academic research, and personal neurofeedback [17]. The device supports both wet and dry electrodes. Wet electrodes use saline solution to enhance conductivity and typically offer higher signal sensitivity but require longer setup and maintenance. In contrast, dry electrodes do not require conductive gels, allowing for quicker setup and greater comfort during prolonged sessions, although they may trade off some signal fidelity [4].

The NeuroSky MindWave Mobile 2 is a low-cost EEG headset that uses a single dry electrode to monitor brain activity. It targets basic applications such as meditation, focus training, and sleep monitoring [1]. While it offers limited functionality compared to multi-channel systems, its simplicity makes it appealing for beginners and non-experts. Both the EPOC+ and MindWave Mobile 2 represent accessible entry points into EEG technology for educational and early-stage research use.

In our study, we initially considered both the Emotiv EPOC+ and the NeuroSky MindWave Mobile 2. Although the MindWave hardware was available, its software was incompatible with modern operating systems at the time of testing, which rendered it unsuitable for experimental use. The Emotiv EPOC+ offered better compatibility, particularly with Windows 11, and came with accessory support that facilitated experimental use. Based on these technical advantages, we selected the Emotiv EPOC+ as the sole EEG device for all study sessions. Section (A) of Figure 2 illustrates the specific components used.

3.3 Participants and Recruitment

The pilot study included five female participants ranging in age from 27 to 54, including one pilot participant and one control participant (see Table 1). All participants volunteered and had no prior experience using EEG technology. Eligibility criteria included: (1) no previous exposure to EEG systems, (2) informed consent to participate, and (3) no known history of neurological conditions.

Given the pilot nature of the study, we used a focused recruitment strategy that yielded a small but relevant sample. Although the sample size was limited, the group was appropriate for an exploratory

[1]https://www.emotiv.com/epoc/
[2]https://store.neurosky.com/pages/mindwave

Figure 2: (A) Emotiv EPOC+ EEG headset, (B) NeuroSky MindWave Mobile 2: Brainwave Starter Kit. Both product images feature short-haired models, which contrasts with the hair-related usability challenges observed in this study.

study that aimed to identify qualitative usability challenges rather than achieve statistical generalization. We conducted the study within a defined research window, which shaped the scope and depth of data collection. Despite the small scale, the study provided meaningful insights into real-world EEG usability challenges and established a foundation for future large-scale investigations.

3.4 Ethical Considerations

We informed all participants about the study's purpose and procedures before obtaining their written consent through a formal consent form. To protect their privacy, we assigned pseudonyms and anonymized all collected data. We stored the data securely and ensured that no personally identifiable information was disclosed at any point during or after the study.

4 Findings

Throughout the sessions, we systematically documented the usability challenges encountered by participants. We complemented these observations with post-study questionnaire responses (see Table 2), which captured participants' self-assessed setup difficulty, comfort, and willingness to repeat the experiment. The key findings from these observations are summarized below:

- **Time for Setup**: Participants with thick hair experienced noticeably longer setup times due to difficulties in achieving stable electrode-to-scalp contact and avoiding hair entanglement with the sensors. These challenges often necessitated repeated rehydration of the electrodes using saline solution, as thick hair absorbed moisture more quickly, reducing conductivity [19]. As one participant noted, *"Not only was it difficult to position the headset, but I also had to re-apply the saline solution a few times as my hair absorbed it, prolonging the setup."* This finding illustrates how hair density directly impacts both setup duration and the maintenance required to ensure functional signal acquisition.
- **Discomfort**: Discomfort was a recurrent issue, particularly among participants with larger head sizes or those wearing glasses, which negatively impacted the overall usability of the EEG headset. The main sources of discomfort were the tightness of the headset and the resulting pressure on the scalp [43]. Participants wearing glasses—such as the control user and User 2—reported compounded difficulties, including both physical discomfort and inconsistent sensor connectivity. For instance, User 2 had to repeatedly adjust her glasses and hair tie to achieve proper electrode placement, resulting in pressure-related discomfort. Additionally, participants like User 2 and User 3 deviated from the recommended wearing method to alleviate discomfort, which likely affected signal consistency. As one participant noted, *"The headset felt too tight, especially around my glasses. Adjusting it was tricky, and it became uncomfortable quickly."* These observations emphasize the need for EEG headsets that can accommodate a wider range of head shapes, sizes, and accessory use cases without compromising comfort or signal quality.
- **Tangling**: Hair tangling emerged as a prominent issue for participants with long or medium-thick hair, leading to increased setup time and additional discomfort. Strands frequently became entangled with the electrodes during headset adjustments, which disrupted signal acquisition and risked compromising data accuracy [13]. One control participant with long, wavy hair described the experience: *"Every time I tried to adjust the headset, my hair would get caught in the sensors. It was quite painful and frustrating, especially with my hair down. Even tying it back with a ribbon didn't help much."* This feedback underscores the necessity for EEG device designs that are sensitive to a range of hair lengths and styles, reducing tangling and enhancing both usability and data integrity.
- **Slippage**: Participants with straight, fine, or silky hair frequently encountered slippage issues, as the headset struggled to maintain a secure grip on the scalp. This instability led to inconsistent sensor contact and necessitated repeated manual adjustments, interrupting the continuity and reliability of EEG recordings. One participant with particularly smooth, straight hair shared, *"I constantly had to readjust the headset because it kept sliding off. My hair's smooth texture seemed to make it difficult for the headset to stay in place."* This feedback highlights the need for improved electrode and headset designs in entry-level EEG systems—particularly solutions that better accommodate a range of hair textures and enhance stability during use [10].
- **Signal Quality and Accuracy**: EEG signal quality and accuracy were closely tied to the ability of the electrodes to maintain stable, direct contact with the scalp [19]. Participants with thick, curly, or textured hair encountered substantial difficulty achieving reliable signal acquisition, often needing to reposition the headset multiple times. The presence of hair products further complicated connectivity by introducing barriers to effective conduction. One participant with thick, curly hair remarked, *"I had to adjust the headset multiple times just to get a decent signal. It felt like my hair type made it harder to get a good reading."* This finding highlights the

Table 1: Participant demographics and EEG setup metrics

Participant	Age	Ethnicity	Height (cm)	Head circumference (cm)	Setup time (m:s)	Total time (m:s)
Pilot user	34	Arab	163	57	30+ minutes	-
Control user	33	Arab	162	54	11:13	32:30
User 1	27	Arab	157	54.4	4:23	12:01
User 2	54	Southeast Asian	148	57.5	3:20	12:29
User 3	34	Southeast Asian	160	51.5	14:30	22:02
User 4	27	Southeast Asian	149	54.7	2:24	11:01
User 5	34	Southeast Asian	165	54.5	2:46	9:20

importance of developing EEG technologies that can support a wide range of hair types and conditions to ensure consistent signal performance across diverse users.

The post-study survey results (Table 2) support and contextualize these observations. Participants with thick or long hair consistently reported high setup difficulty scores (4 or 5). Those with larger head sizes or additional factors, such as the use of eyeglasses, described the headset as uncomfortable. These responses align closely with observational findings, emphasizing the influence of physical characteristics on the EEG user experience. Tangling and slippage also appeared frequently, especially among participants with long, wavy, or smooth hair textures. Taken together, the qualitative responses and usability ratings reinforce the importance of accommodating hair and head diversity in EEG device design and during participant selection in EEG studies to promote greater inclusivity.

5 Discussion

This study identified several usability challenges that female participants encountered while using entry-level EEG devices in user studies. Findings indicate that head size and hair type have a significant influence on EEG usability. Therefore, researchers should account for these factors when designing studies and recruiting participants. Moreover, reported comfort levels varied with head size and duration of headset use, suggesting that physical comfort affects participants' willingness to engage in future EEG research.

To address the usability challenges identified in this study, EEG hardware designers should prioritize inclusive and adaptable designs that accommodate users with larger head sizes, thick hair, or oily scalps. Furthermore, researchers should account for increased setup time when planning and conducting EEG studies. In response to these challenges, promising areas for innovation include designing electrodes that can penetrate and maintain contact through dense or textured hair [10], creating adjustable headsets that fit a broader range of head sizes and hairstyles [22], and selecting materials that interact minimally with hair products and scalp oils to preserve electrode connectivity [32]. Improving the moisture retention of wet electrode systems may also reduce the need for frequent rehydration, benefiting users whose hair rapidly absorbs saline solution [37]. Together, these improvements can help develop more inclusive, reliable, and user-friendly EEG-based BCIs for a broader range of users.

In addition to these hardware concerns, this study showed that the interaction between hair characteristics and EEG devices is a critical consideration when designing EEG-based BCIs. The usability challenges observed, such as poor fit, slippage, and inconsistent signal quality, highlight the need for manufacturers to address the specific difficulties female users encounter. Researchers should remain attentive to these factors when designing studies, as they directly affect data quality and the feasibility of EEG-based research.

Significantly, these usability concerns extend beyond the lab. In real-world EEG applications such as classroom neurofeedback [15], remote cognitive monitoring [42], and clinical rehabilitation [38], poor usability can reduce both user compliance and data reliability. Barriers related to head size, hair type, and comfort may disproportionately affect specific populations. When left unaddressed, these barriers can limit participation and reinforce inequities in access to neurotechnology.

The findings of this study carry important implications for both the EEG and HCI communities, offering critical insights to inform the design of EEG devices that more effectively accommodate female users with diverse hair types and head sizes. These considerations are especially vital for the development of EEG-based technologies aimed at broad, real-world adoption, where inclusivity and usability across varied user populations are essential for success. These considerations are especially vital for the development of EEG-based technologies aimed at broad, real-world adoption, where inclusivity and usability across varied user populations are essential for success.

Although this study focused on general setup usability, the challenges identified may also affect other EEG applications, including neurofeedback [46], emotion recognition [33], and cognitive training, where sustained signal quality is essential. Participants from different age groups or with varying cognitive or physical needs may face additional usability barriers [13]. To expand the scope of these findings, future work can apply the findings from this study across different contexts and populations. Researchers can also examine how scalp condition and the use of hair products, such as oils, gels, or sprays, affect electrode conductivity and introduce variability in signal quality.

Several limitations of this study warrant consideration. First, the small sample size (five female participants) limits the generalizability of the findings. However, the study aimed to explore usability issues specific to females using EEG devices. Future research should expand on these results using larger and more diverse participant groups. Second, all participants belonged to a similar age range, which may not accurately represent the broader experiences

Table 2: Responses to the questions after the user study concerning hair thickness, easy of setup, willingness to repeat experiment, and comfort of the EEG headset.

Participant	Hair type (density, texture, length)	Setup challenges rate (1-5)	Experiment repetition rate (1-5)	Comfort of EEG headset
Pilot user	Thick, curly, long	5	1	Very uncomfortable
Control user	Thick, wavy, long	5	3	Uncomfortable
User 1	Medium, curly, short	1	5	Comfortable
User 2	Thick, straight, medium	4	4	Uncomfortable
User 3	Thick, straight, long	5	4	Uncomfortable
User 4	Medium, straight, medium	5	5	Comfortable
User 5	Medium, straight, long	3	5	Comfortable

of women across different age groups, backgrounds, or lifestyles. Third, the study included a limited range of hair types and lengths. Including individuals with coarse, tightly coiled, or otherwise underrepresented hair textures, along with participants from more varied ethnic backgrounds, would provide deeper insight into how intersectional factors affect EEG usability and inclusivity.

Moreover, this study focused specifically on entry-level EEG devices, which may have usability limitations that more advanced systems with sophisticated sensor technologies are better equipped to handle. Nevertheless, achieving reliable electrode-to-scalp contact remains essential across all EEG devices, regardless of technical complexity. Usability challenges related to hair type, head size, and comfort are likely to persist across device tiers. Thus, future research should evaluate higher-end EEG systems to determine how effectively they address the issues identified in this study, particularly for female participants with diverse hair and head characteristics.

5.1 Limitations and Threats to Validity

This exploratory study faced practical constraints that limit the generalizability of its findings. The sample size was small (N = 5), and the participants who volunteered shared a similar demographic background, which reduced diversity. We intentionally scoped the study to include only women, focusing on hair-related usability challenges that most commonly affect women.

We used only one EEG device (Emotiv EPOC+) in this study. Although we had access to a second device (MindWave Mobile 2), unsupported software made it unusable despite its functioning hardware. Relying on a single device limits the broad applicability of our findings, as specific hardware features may influence usability. However, researchers in HCI and BCI commonly use the Emotiv EPOC+ [33, 41]. In this study, we identify practical challenges that previous research has often overlooked [18].

Participants reported difficulty putting on the Emotiv EPOC+ headset, especially those with thick or textured hair, larger head sizes, or who wore glasses. To improve the fit, some participants extended the headset's electrode-supporting arms beyond the recommended range, which could eventually damage the device. Participants who spent more time adjusting the headset also reported greater discomfort, largely due to repeated repositioning and increased pressure on the scalp. Although we used a new device that showed no signs of wear, previous research has shown that saline-based electrodes may oxidize with extended use [9], which could degrade signal quality and require periodic replacement.

The usability challenges we identified may contribute to broader systemic biases in EEG-based HCI research. When certain user groups—such as individuals with thick, curly, or long hair—face greater barriers to participation, they may be underrepresented in datasets and overlooked in EEG hardware design [31, 40]. This exclusion can undermine the generalizability of EEG research and reinforce inequities in who benefits from brain-computer interface technology [8, 40]. Future work should address these dynamics by applying inclusive design principles to both EEG hardware development and research planning.

6 Conclusion

This exploratory study examined the usability challenges faced by five female participants during user studies involving an entry-level EEG device. Observed difficulties—such as electrode contact issues for participants with thicker hair or larger head sizes, and slippage in those with fine, straight hair—highlighted variability in headset performance and comfort. These observations suggest that usability is a critical factor to consider in EEG study design [27]. By surfacing these overlooked barriers, the study offers preliminary insights that may inform the development of more inclusive EEG technologies and guide future research in both EEG and HCI. The work contributes to ongoing conversations around equitable neurotechnology design and its application in user-centered contexts.

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