



The Efficacy and User Perception of Digital Health Interventions for Tinnitus: A Mixed-Methods Evaluation

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Abstract. Background: Tinnitus is a chronic auditory disorder affecting an estimated 10–15% of the United Kingdom adult population and approximately 50 million Americans, characterised by the perception of phantom sounds in the absence of external stimuli. Despite the absence of a definitive cure, mobile health (mHealth) applications have emerged as accessible self-management tools. However, critical gaps remain in the evaluation of these applications across dimensions of accessibility, evidence-based content, functionality, and personalisation. **Objective:** This study aimed to conduct a comprehensive, mixed-methods evaluation of mobile applications for tinnitus management, focusing on their efficacy, user satisfaction, and the tension between high overall positive sentiment and persistent limitations in evidence-based content, personalisation, and user accessibility. **Methods:** A three-strand mixed-methods design was employed: (1) sentiment analysis of 13,096 user reviews from 42 tinnitus management applications across Google Play and Apple App Store (July–December 2022), collected using Appbot; (2) a cross-sectional online survey of 171 participants with self-reported tinnitus, conducted between March and June 2024; and (3) in-depth semi-structured interviews with 19 purposively selected participants. Quantitative data were analysed using descriptive statistics, chi-square tests of independence, and Spearman rank correlation. Qualitative data were thematically analysed using NVivo. **Results:** Sentiment analysis revealed that 72.38% of 13,096 reviews were positive, and the overall average app rating was 4.29 out of 5 stars. Google Play exhibited higher positive sentiment (79.49%) compared to iOS (65.42%). ReSound Tinnitus Relief was the top-rated application by volume (n=3,452 reviews; mean rating=4.61). Survey findings revealed that 91.4% of 171 tinnitus sufferers had never used a tinnitus-specific mobile application. Among the 14 active app users, ambient sounds (71.43% useful/very useful) and information about tinnitus (64.29%) were the most valued features. Spearman rank correlation confirmed significant positive associations between app feature information and health content quality ($p=0.73$, $P<.001$), app use and user experience ($p=0.68$, $P<.001$), and app use and well-being indicators ($p=0.71$, $P<.001$). Interview data revealed four core themes: apps as lifesavers for sleep and emotional stress management, value and connectivity through app use, relevance of educational content, and effects on tinnitus management and well-being. **Conclusions:** Tinnitus management mobile applications demonstrate significant promise as tools for sleep improvement, stress reduction, and patient education, with strong positive user sentiment. However, a paradoxical finding, high satisfaction among the 8.6% of users who adopt apps versus 91.4% non-adoption, reveals major systemic barriers including low awareness, inadequate personalisation, and insufficient evidence-based content. Collaborative development among app developers, clinicians, and researchers is essential to close this efficacy–accessibility gap.

Keywords: tinnitus management; mobile health applications; mHealth; sentiment analysis; mixed-methods; user experience; digital health; sleep; well-being; United Kingdom; Nigeria



I. Introduction

Tinnitus is an auditory phantom disorder characterised by the perception of internally generated elemental sounds, often described as ringing, humming, buzzing, chirping, or clicking, in the absence of externally identifiable sources [1,2]. It is most common in older adults, with a considerable socioeconomic impact [3,4]. Tinnitus is estimated to affect approximately 10–15% of the UK adult population, with one in seven adults experiencing the condition [5]. In the United States, approximately 50 million Americans have been diagnosed with tinnitus [6]. Despite its prevalence, tinnitus has no cure, and management strategies focus on coping, symptom reduction, and quality-of-life improvement [7,8].

Traditional management options for tinnitus are diverse and require a multidisciplinary approach, including pharmacotherapy, cognitive behavioural therapy (CBT), sound therapy, and tinnitus retraining therapy (TRT) [9,10]. More recently, mobile health (mHealth) applications have emerged as scalable and accessible adjuncts to standard tinnitus care. The most current mobile apps integrate expert systems, speech recognition, machine learning, and other cutting-edge technologies [11]. Several studies have identified a rapidly expanding landscape of tinnitus-specific applications [12,13,14]. Smith and Sereda [15] identified nearly 250 tinnitus-related applications across major app stores. These apps primarily offer sound therapy, relaxation exercises, educational content, cognitive behavioural strategies, and mindfulness techniques, addressing both the perceptual and psychological components of tinnitus.

Despite the proliferation of these applications, a critical gap exists in our comprehensive understanding of their real-world efficacy, user perceptions, and barriers to adoption. Prior studies have largely evaluated individual apps [16,17], catalogued features without assessing usage patterns [18,19], or applied standardised quality instruments such as the Mobile App Rating Scale (MARS) without incorporating the perspectives of tinnitus patients themselves [12,20]. Furthermore, no prior study has applied a simultaneous, large-scale sentiment analysis alongside primary survey and interview data to generate a holistic picture of the mobile tinnitus app ecosystem.

This study addresses this gap by conducting a comprehensive mixed-methods evaluation of 42 tinnitus management applications using 13,096 user reviews, alongside a survey of 171 tinnitus patients and in-depth interviews with 19 participants. The study was guided by an integrated theoretical framework synthesising the Theory of Consumption Values (TCV) [21], Social Choice Theory [22], Desire Theory [23], and Subjective Well-Being (SWB) Theory [24]. This framework enabled the analysis of app adoption through multidimensional value lenses spanning functional, emotional, epistemic, social, and conditional dimensions.

To address these gaps, this study outlines four core research objectives aimed at understanding how mobile applications support the well-being and daily management needs of individuals living with tinnitus. Specifically, the investigation explores how these apps enhance overall subjective well-being, identifies the specific usage choices and multidimensional values, such as functional and emotional benefits, that patients assign to them, evaluates the relevance of app-delivered information to users' unique clinical and psychological needs, and ultimately assesses the measurable effects of mobile app engagement on long-term tinnitus management.

II. Methods

Research Design

This study employed a mixed-methods research design, integrating three complementary strands: sentiment analysis of app store reviews, a cross-sectional online survey, and in-depth semi-structured interviews. An abductive research approach was adopted, combining both deductive and inductive reasoning to navigate the dual nature of tinnitus as both a biomedical condition and a subjective lived experience [25,26]. The study's philosophical underpinnings reflect a pragmatic epistemological stance, which prioritises practical outcomes while acknowledging the value of both quantitative patterns and qualitative narratives [27,28].

**Strand 1: Sentiment Analysis****Data Collection and Sample Frame**

Tinnitus management applications were identified from the Google Play Store and Apple App Store using Appbot, a commercial web-scraping and analytics platform. The keyword “tinnitus” was used to retrieve an initial pool of 77 distinct mobile applications across both platforms. After applying structured inclusion criteria, availability on both platforms, reviews posted between July and December 2022, and a minimum of five user reviews per application, a final sample of 42 tinnitus management applications was retained, yielding a total dataset of 13,096 user reviews [29].

Appbot’s proprietary Natural Language Processing (NLP) algorithms pre-classified each review into one of four sentiment categories: positive, negative, neutral, or mixed. The Python libraries Pandas, NumPy, Matplotlib, Gensim, and Counter were employed exclusively for data aggregation, descriptive statistics, and visualisation. No custom sentiment classification was performed.

Strand 2: Survey**Participants and Procedure**

An online cross-sectional survey was disseminated to individuals with self-reported tinnitus through tinnitus support associations, closed social media communities (estimated combined membership of approximately 10,000 individuals), and corporate medical facility registries in both the United Kingdom and Nigeria. The sample size was determined using Yamane’s formula for a population of 13,095 and a 5% margin of error, yielding a required sample of 388; a final sample of 171 participants completed the survey between March and June 2024. Survey items assessed demographic characteristics, tinnitus history, mobile app adoption and frequency of use, feature-level usefulness ratings, health content evaluation, technical and security perceptions, usability, and subjective well-being. Informed consent was obtained from all participants prior to participation. Quantitative data were analysed using descriptive statistics and inferential tests including chi-square tests of independence (to examine associations between demographic variables and app use), and Spearman’s rank correlation coefficient (to test the hypothesised relationships between app feature quality, user experience, and well-being outcomes). All inferential statistics were computed manually following standard procedures [30,31] and cross-verified in Microsoft Excel.

Strand 3: Qualitative Interviews

A purposive sub-sample of 19 participants from the survey pool was recruited for in-depth semi-structured interviews. Interview sessions lasted 30–45 minutes and were conducted via face-to-face meetings or online platforms (Zoom, Skype, or Microsoft Teams) based on participant preference [32,33]. Sessions were audio-recorded with participant consent and transcribed using NVivo transcription software, supplemented by manual review. Thematic analysis was conducted using NVivo, guided by the integrated theoretical framework. Ethical approval was obtained from Northumbria University’s Faculty of Engineering and Environment Ethics Committee.

Ethical Considerations

Ethical approval was granted by the Northumbria University Faculty of Engineering and Environment Ethics Committee. All participants provided informed consent prior to participation. Data were anonymised, and confidentiality was maintained throughout the study. Participants were informed of their right to withdraw at any stage without consequences.

III. Results**Strand 1: Sentiment Analysis****Application Ratings**

The 42 tinnitus management applications included in the sentiment analysis accumulated 13,096 user reviews. The distribution of star ratings revealed a strong positive skew: 9,327 reviews (67.69%) were rated 5 stars, 1,426 (10.34%) were rated 4 stars, 599 (4.34%) were rated 3 stars, 349 (2.53%) were rated 2 stars, and 1,395 (10.10%) were rated 1 star. The overall average rating across all applications was 4.29 out of 5.



Table 1. Distribution of Application Ratings

Rating (Stars)	Count (n)	Percentage (%)
1 Star	1,395	10.10
2 Stars	349	2.53
3 Stars	599	4.34
4 Stars	1,426	10.34
5 Stars	9,327	67.69
Total	13,096	100.00

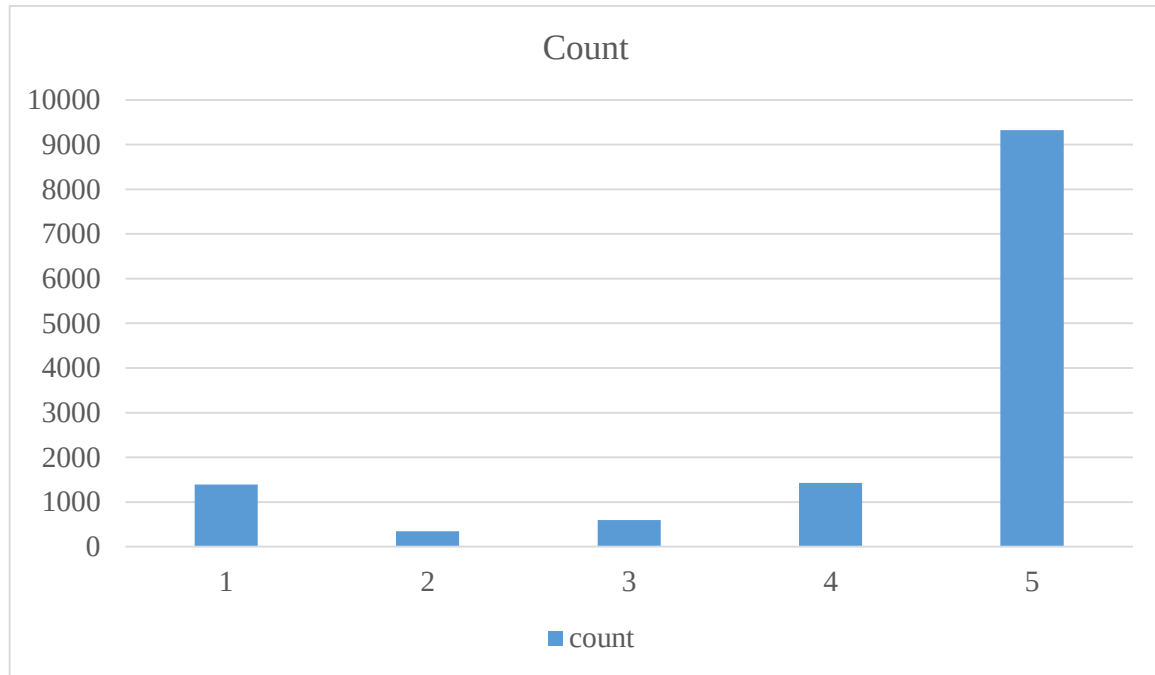


Figure 1. Distribution of All Application Ratings (n=13,096).

The bar chart illustrates the strong positive skew, with 5-star ratings (n=9,327; 67.69%) substantially outnumbering all other rating categories combined (n=3,769; 32.31%).

Although three applications (Tinnitus Relief Sound Therapy, Pauze Your Tinnitus, and MyTinnitus: Tinnitus Tracker) achieved a perfect average rating of 5.0 stars, the application identified as the most suitable overall was ReSound Tinnitus Relief. Despite a slightly lower average rating of 4.61 stars, it was supported by a substantially larger number of user reviews (n=3,452), reflecting broader engagement and greater statistical reliability. Table 2 presents the top five applications by volume of reviews.

Table 2. Top Five Tinnitus Applications by Review Volume

App Name	Average Rating	No. of Reviews (n)
ReSound Tinnitus Relief	4.61	3,452
Rain Rain Sleep Sounds	4.69	2,198
Beltone Tinnitus Calmer	4.64	2,136
TaoMix 2: Sleep Sounds & Focus	2.94	1,527
Portal – Immersive Escapes	4.48	807

Rating Distribution by App Store Platform

Substantial platform-level differences were observed in rating distributions. Google Play recorded a higher proportion of 5-star reviews (73.88%) compared to iOS (68.62%), and a lower proportion of 1-star reviews (5.29% vs. 15.90%). The average rating on Google Play was 4.49, compared to 4.10 on iOS (Table 3).

Table 3. Rating Distribution by App Store Platform (%)

Platform	1 Star (%)	2 Stars (%)	3 Stars (%)	4 Stars (%)	5 Stars (%)	Average Rating
Google Play	5.29	2.30	4.17	14.37	73.88	4.49
iOS App Store	15.90	3.02	4.97	7.48	68.62	4.10

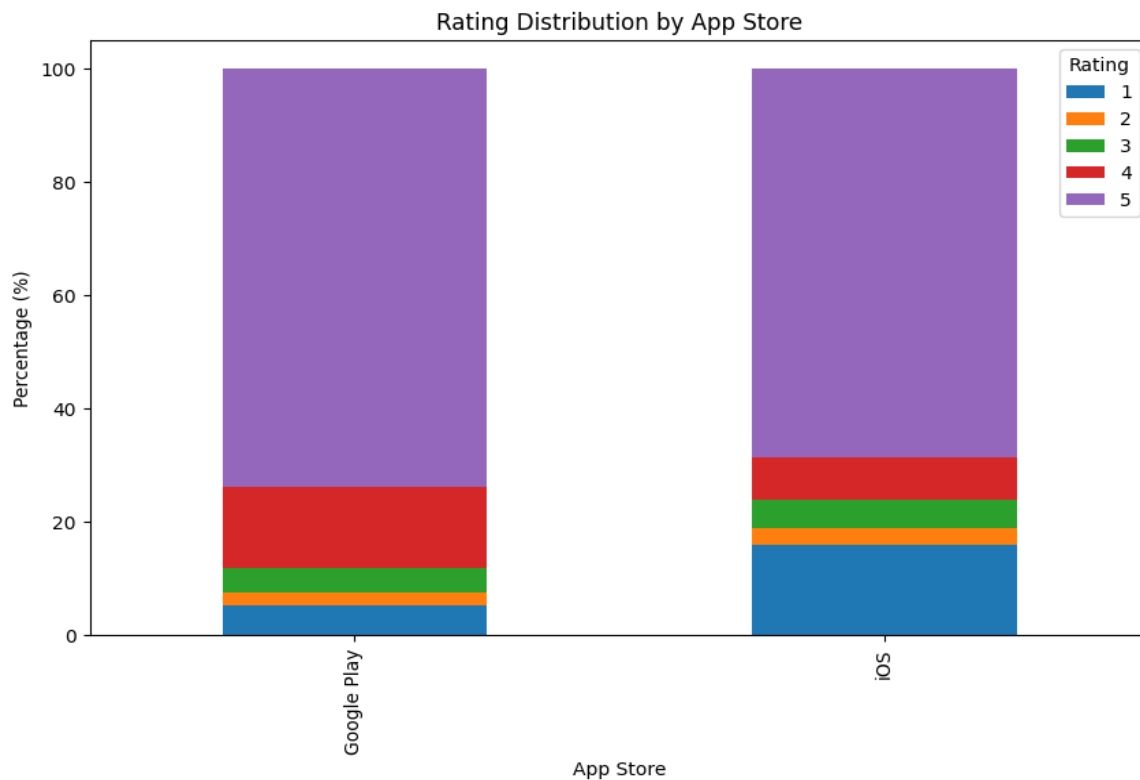


Figure 2. Rating Distribution by App Store Platform.

Stacked bar chart comparing the percentage distribution of 1–5 star ratings between Google Play (n=8,341) and iOS (n=4,755).

Sentiment Distribution

The overall sentiment distribution revealed a dominant positive sentiment orientation. Of 13,096 reviews, 9,478 (72.38%) were classified as positive, 1,952 (14.91%) as negative, 950 (7.26%) as neutral, and 714 (5.45%) as mixed (Table 4).

Table 4. Distribution of Application Sentiments Across All Reviews

Sentiment Category	Count (n)	Percentage (%)
Positive	9,478	72.38
Negative	1,952	14.91
Neutral	950	7.26
Mixed	714	5.45
Total	13,096	100.00

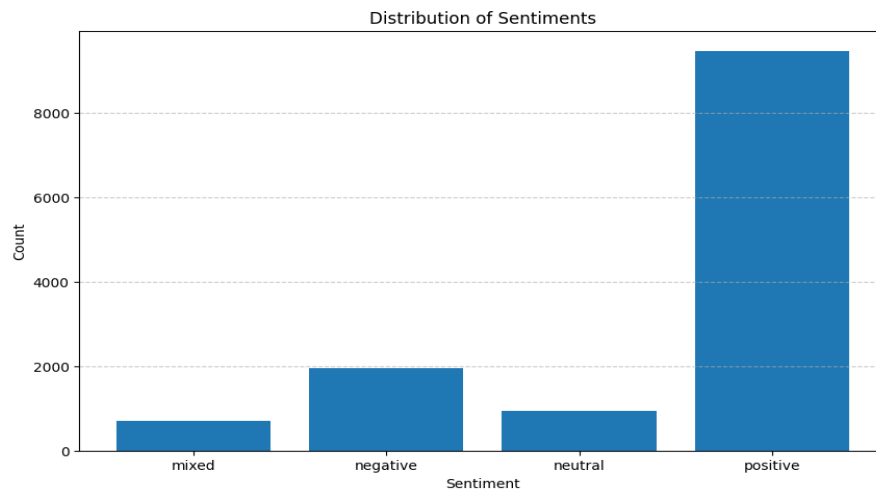


Figure 3. Distribution of All Application Sentiments.

Positive sentiment dominated, comprising 72.38% of all 13,096 reviews, while negative sentiment accounted for 14.91%. The relationship between rating and sentiment was strongly directional: reviews rated 1 and 2 stars generated no positive sentiment (0%), while reviews rated 4 and 5 stars generated no negative sentiment (0%). At 3 stars, sentiment was distributed as 58.10% negative, 24.37% positive, and 17.53% neutral. As ratings increased from 3 to 5 stars, positive sentiment rose from 24.37% to 89.42%, while negative sentiment declined correspondingly (Table 5).

Table 5. Relationship Between Rating and Sentiment (%)

Rating	Mixed (%)	Negative (%)	Neutral (%)	Positive (%)
1 Star	2.15	93.76	4.09	0.00
2 Stars	8.60	84.81	6.59	0.00
3 Stars	0.00	58.10	17.53	24.37
4 Stars	17.11	0.00	13.18	69.71
5 Stars	4.40	0.00	6.19	89.42

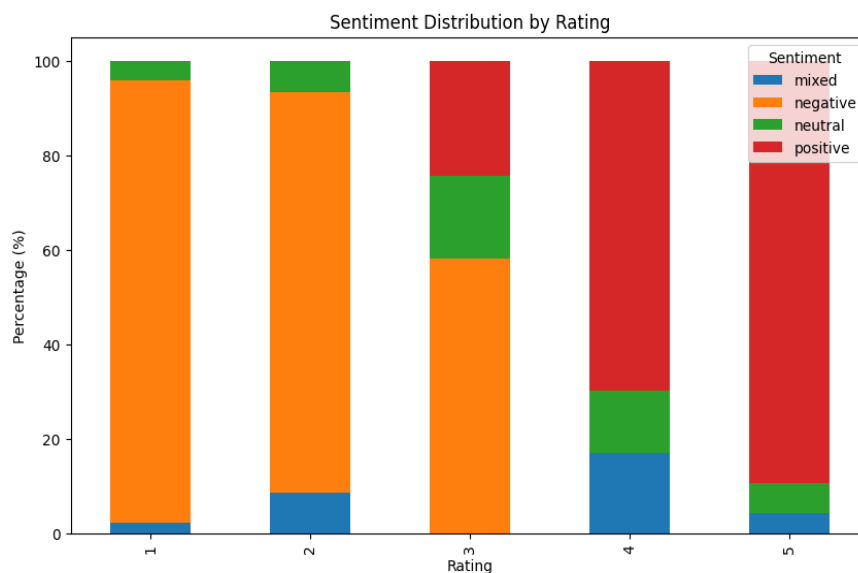


Figure 4. Sentiment Distribution by Star Rating.

Stacked bar chart showing the progressive shift from negative to positive sentiment as star ratings increase from 1 to 5.

Sentiment by App Store Platform

Platform-level sentiment analysis revealed that Google Play users exhibited substantially higher positive sentiment (79.49%) compared to iOS users (65.42%). Conversely, iOS users expressed considerably more negative sentiment (21.08%) than Google Play users (8.61%), highlighting a significant platform disparity in user experience (Table 6).

Table 6. Sentiment Distribution by App Store Platform (%)

Platform	Positive (%)	Negative (%)	Neutral (%)	Mixed (%)
Google Play	79.49	8.61	7.28	4.61
iOS App Store	65.42	21.08	7.23	6.28

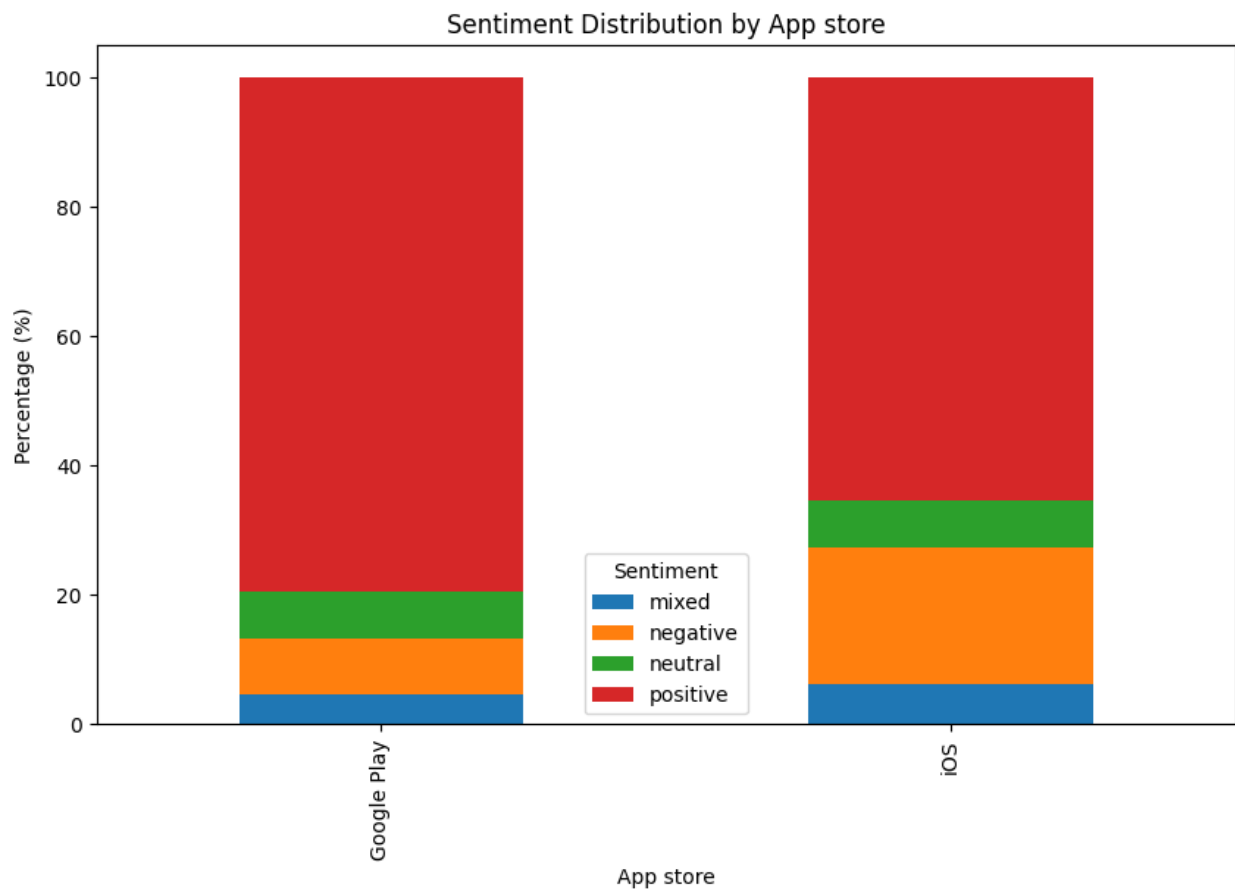


Figure 5. Sentiment Distribution by App Store Platform.

Stacked bar charts comparing positive, negative, neutral, and mixed sentiment proportions between Google Play and iOS.

Topic Analysis

Topic modelling of user reviews identified ten dominant discussion themes (Table 7). "Satisfied users" emerged as the most prominent positive topic (n=5,404), followed by "Audio" (n=2,376), "Use cases" (n=1,154), and "Design & UX" (n=1,077). In the negative sentiment context, "Audio" remained the foremost concern (n=221), followed by "Bugs" (n=198), "Dissatisfied users" (n=173), and "Pricing" (n=147). Topics such as "Audio," "Design & UX," "Customer Support," and "Pricing" appeared in both positive and negative contexts, underscoring the multifaceted nature of user experience.



Table 7. Top Ten Discussion Topics and Their Counts Across All Reviews

Rank	Topic	Total Count (n)	Positive Count (n)	Negative Count (n)
1	Satisfied Users	5,404	4,905	,
2	Audio	2,376	1,829	221
3	Use Cases	1,154	998	45
4	Design & UX	1,077	809	133
5	Customer Support	630	508	41
6	Pricing	556	309	147
7	Bugs	516	193	198
8	Complexity	466	404	27
9	Feature Requests	340	221	47
10	Performance	264	160	51

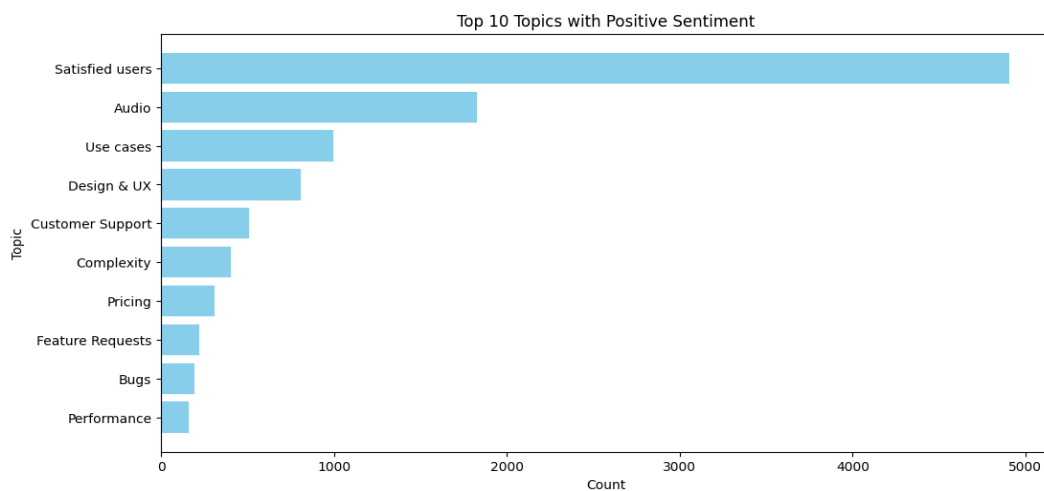


Figure 6. Top 10 Topics with Positive Sentiment.

Horizontal bar chart showing topic frequency among positively classified reviews. “Satisfied Users” (n=4,905) and “Audio” (n=1,829) dominated positive discussion.

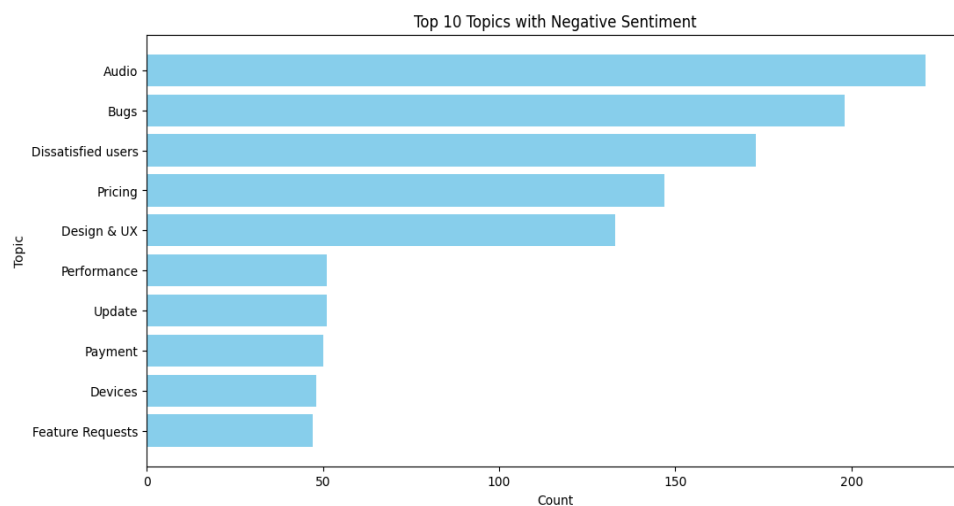


Figure 7. Top 10 Topics with Negative Sentiment.



Horizontal bar chart showing topic frequency among negatively classified reviews. “Audio” (n=221) and “Bugs” (n=198) were the most prevalent concerns.

Strand 2: Survey Results

Participant Characteristics

A total of 171 participants completed the survey. The demographic profile is summarised in Table 8. The sample was predominantly female (66.3%) and older adults, with 44.8% aged 60–79 years. Most participants reported tinnitus in both ears (69.3%), and 39.3% had experienced symptoms for 5–14 years. Critically, 91.4% (n=149) reported that they had never used a mobile application to manage their tinnitus, while only 8.6% (n=19, with 14 completing the app-specific survey items) reported active app use.

Table 8. Demographic Characteristics of Survey Participants (N=171)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Female	108	66.3
	Male	53	30.7
	Prefer not to say/Other	10	3.0
Age (years)	18–29	8	3.7
	30–49	49	26.4
	50–59	38	23.3
	60–79	73	44.8
	80+	4	1.8
Employment	Full-time	68	41.7
	Retired	52	30.7
	Part-time/Other	38	27.6
Tinnitus Location	Both ears	116	69.3
	Left ear only	30	16.6
	Right ear only	25	14.1
Duration of Symptoms	< 5 years	57	32.5
	5–14 years	65	39.3
	≥15 years	49	28.2
App Adoption	Yes	19	8.6
	No	149	91.4

Feature Usefulness Among App Users (n=14)

Among active app users (n=14), feature utility ratings varied substantially across categories. Sound-based features demonstrated the highest perceived usefulness: ambient sounds were rated useful or very useful by 71.43% of participants, sound enrichment by 57.14%, and breathing exercises by 50.00%. Educational content, specifically information about tinnitus, was rated useful or very useful by 64.29%, making it the highest-rated individual feature. Conversely, more advanced sound-based features including binaural beats (71.43% unsure), isochronic tones (64.29% unsure), and hypnosis for tinnitus (64.29% unsure) suffered from high levels of uncertainty, suggesting unfamiliarity rather than active rejection (Table 9).

Table 9. Feature Usefulness Ratings Among Active App Users (n=14)

Feature Category	Feature	Useful/Very Useful (%)	Not Useful/Poor (%)	Unsure (%)
Sound-Based	Ambient Sounds	71.43	14.28	14.29
Sound-Based	Sound Enrichment	57.14	14.28	28.57
Sound-Based	Notched Music	28.57	14.29	57.14
Sound-Based	Binaural Beats	7.14	21.43	71.43
Sound-Based	Isochronic Tones	21.43	14.29	64.29
Relaxation	Breathing Exercises	50.00	35.71	14.29
Relaxation	Muscle Relaxation	50.00	28.57	21.43



Meditation	Guided Meditation	42.86	28.58	28.57
Meditation	Mindfulness Techniques	50.00	28.57	21.43
Education	Information about Tinnitus	64.29	21.43	14.29
Education	Information about Sound Therapy	57.15	21.43	21.43
Education	Counselling	50.00	21.43	28.57
Hypnosis	Hypnosis for Tinnitus	14.29	21.43	64.29
Hypnosis	Hypnosis for Other Problems	21.43	21.43	57.14

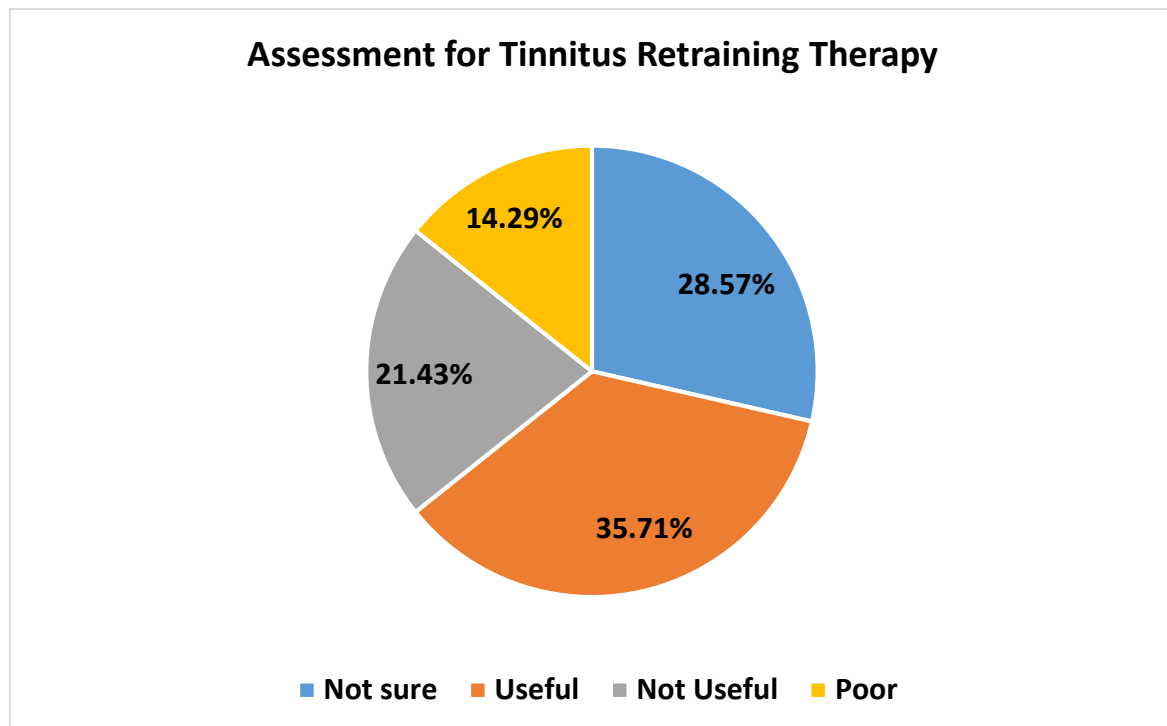


Figure 8. Feature Usefulness Ratings by Category Among Active App Users (n=14).

Grouped bar charts showing the proportions of useful/very useful, not useful/poor, and unsure responses across all evaluated feature categories.

App Quality Dimensions: Health Content, Technical Performance, Security, and Usability

Quality evaluation items demonstrated consistently high importance ratings across health content, technical, security/privacy, and usability dimensions. Quality of health information was considered important or very important by 92.86% of respondents, accuracy of app store description by 100%, and appropriate interpretation of health data by 78.57%. Security items were uniformly highly rated: data sharing transparency (85.71% important/very important), breach notification (85.71%), and anonymisation (78.57%). Usability was the strongest-performing category: functionality was rated important or very important by 100% of respondents, and installation and setup by 92.86% (Table 10).



Table 10. Summary of App Quality Dimension Ratings Among Active App Users (n=14)

Quality Dimension	Criterion	Important/Very Important (%)
Health Content	Quality of Information	92.86
Health Content	Potential for Harm	92.85
Health Content	Appropriate Measurement	85.72
Health Content	Appropriate Data Interpretation	78.57
Transparency	Accuracy of App Store Description	100.00
Transparency	Cost Transparency	71.43
Transparency	Consent	71.43
Technical	Software Performance/Stability	85.71
Technical	Interoperability	71.42
Security/Privacy	Protection Against Theft/Viruses	85.72
Security/Privacy	Data Sharing	85.71
Security/Privacy	Breach Notification	85.71
Usability	Functionality	100.00
Usability	Installation and Setup	92.86
Usability	Customisation/Tailoring	85.71
Usability	Ease of Use (Low Literacy)	78.57

Inferential Statistics: Hypothesis Testing

Three hypotheses were tested using Spearman's rank correlation coefficient (Table 11). All three null hypotheses were rejected at $P < .001$, confirming statistically significant positive associations:

- **Hypothesis 1:** A significant positive correlation was found between app feature information and health content quality ($\rho = 0.73$, $P < .001$), indicating that the richer the informational features, the higher the perceived health content quality.
- **Hypothesis 2:** A significant positive correlation was found between mobile app use and user experience ($\rho = 0.68$, $P < .001$), confirming that more frequent app engagement is associated with better user experience ratings.
- **Hypothesis 3:** A significant positive correlation was found between mobile app use and well-being indicators ($\rho = 0.71$, $P < .001$), demonstrating that app engagement is associated with improvements in self-reported well-being.

Chi-square tests of independence revealed no statistically significant associations between gender and app use ($\chi^2 = 2.41$, $P = .49$) or age and app use ($\chi^2 = 5.18$, $P = .27$), indicating that mobile app adoption among tinnitus patients does not significantly differ by demographic characteristics.

Table 11. Summary of Spearman Rank Correlation Results

Hypothesis	Independent Variable	Dependent Variable	Spearman ρ	P Value	Decision
H1	App Feature Information	Health Content Quality	0.73	<.001	Reject H_0
H2	Mobile App Use	User Experience	0.68	<.001	Reject H_0
H3	Mobile App Use	Well-Being Indicators	0.71	<.001	Reject H_0

Strand 3: Qualitative Interview Results**Participant Characteristics**

A total of 19 participants were interviewed (Table 12), representing diverse tinnitus severity levels, durations of experience, and mobile app engagement histories (high users, low/dropped users, and non-users/alternative coping strategy users).

Table 12. Demographic Characteristics of Interview Participants (N=19)

Characteristic	Category	Frequency (n)
Gender	Female	11
	Male	8
Tinnitus Duration	< 5 years	6



	5–14 years	8
	≥15 years	5
App Engagement History	High user	10
	Low/dropped user	6
	Non-user / alternative coping	3

Theme 1: Apps as Lifesavers – Sleep and Emotional Well-Being

The most pervasive theme across interviews was the role of tinnitus management apps in addressing sleep disturbance and emotional stress, the two aspects of tinnitus most commonly rated as severely impactful. Participants described apps as “life-savers” for nighttime functioning, with sound-based features (particularly ambient sounds and white noise) enabling sleep onset that participants described as otherwise impossible:

“The app was the first thing that ever helped me sleep properly in three years. I play it every single night.” (Participant 7, Female, age 62)

Emotional stress management was a closely related sub-theme. Participants described how tinnitus-related anxiety and hypervigilance diminished with consistent app use, particularly through guided meditation and mindfulness features. Several participants noted that the accessibility of apps, available at 3am, free from clinical gatekeeping, was a distinct and irreplaceable advantage over face-to-face services.

Theme 2: App Use Choices, Value, and Connectivity

Participants articulated diverse reasons for selecting specific applications, ranging from peer recommendations through online support communities to clinician suggestions. The perceived value of apps was assessed across functional (practical utility), emotional (relief and comfort), and epistemic (knowledge acquisition) dimensions, closely aligning with TCV’s theoretical propositions [21]. Social connectivity emerged as a distinctive sub-value: several participants described how apps linked them to online tinnitus communities, reducing the isolation commonly associated with the condition:

“I found other people going through the same thing. That connection was as therapeutic as the sounds.” (Participant 12, Male, age 54)

Management effectiveness was a critical criterion: participants who reported high engagement had identified apps that specifically addressed their dominant symptom profile (sleep disruption, anxiety, or hearing support). Participants who had discontinued app use frequently cited a mismatch between their specific needs and available app features.

Theme 3: Relevance of Educational Content

Participants consistently rated educational content as one of the most valued aspects of tinnitus management apps, reinforcing the quantitative finding that information about tinnitus was the highest-rated individual feature (64.29% useful/very useful). Knowledge provision through apps fostered resilience, enabling participants to reframe their experience of tinnitus and engage more effectively with clinical services:

“The app explained why I hear what I hear. That knowledge changed everything. I stopped being afraid of the sound.” (Participant 3, Female, age 71)

Connectivity with other tinnitus sufferers through app-embedded community features also functioned as an educational channel, with participants sharing coping strategies and reporting significant reductions in the perceived uniqueness of their experience.

Theme 4: Effects on Tinnitus Management and Well-Being

Participants who engaged consistently with tinnitus management apps reported measurable positive effects across multiple well-being dimensions: reduced anxiety and depression scores, improved sleep quality, better daily functioning, and an enhanced sense of self-efficacy in managing their condition. Situation monitoring features (symptom trackers) and community



connection elements further supported participants' capacity for ongoing self-management. However, a subset of participants described "mixed feelings", acknowledging that apps provided meaningful short-term relief while recognising that they did not address the underlying auditory pathology:

"It helps me cope, but the ringing is still there. I sometimes feel frustrated that the app is managing symptoms but not solving the problem." (Participant 16, Male, age 48)

This finding reflects the inherent limitation of mHealth tools in conditions without a definitive cure and highlights the continued need for clinician involvement in tinnitus management pathways.

IV. Discussion

Principal Findings

This study presents the largest mixed-methods evaluation of tinnitus management mobile applications to date, combining sentiment analysis of 13,096 user reviews, survey data from 171 tinnitus patients, and qualitative interviews with 19 participants. The overarching finding is one of significant paradox: tinnitus management apps generate overwhelmingly positive user sentiment (72.38%) and high average ratings (4.29/5), yet are adopted by only 8.6% of tinnitus sufferers in this sample. This disjunction, between the demonstrated value of apps for those who use them and the near-total non-adoption among those who do not, constitutes the central empirical and practical challenge identified by this research.

The high positive sentiment observed in this study aligns with prior app evaluation studies [12,15,17], which have similarly documented strong user satisfaction among tinnitus app users. ReSound Tinnitus Relief's dominance ($n=3,452$; 79.43% positive from positive reviews), consistent with Kutuba et al.'s [16] clinical evaluation finding significant symptom reduction with the same application, provides convergent evidence of its therapeutic value. The platform disparity (Google Play 79.49% positive vs iOS 65.42% positive; 21.08% negative on iOS) replicates patterns observed in health app evaluations more broadly [29,34] and may reflect differences in user base composition, app store review culture, or platform-specific technical performance.

The Non-Adoption Paradox

The finding that 91.4% of tinnitus sufferers surveyed had never used a mobile application for tinnitus management is the most striking and policy-relevant result of this study. This rate significantly exceeds the non-adoption rates implied in prior literature, which has focused primarily on evaluating apps among users who have already adopted them [12,13,14]. Critically, chi-square testing confirmed that non-adoption is not significantly associated with gender or age ($P>.27$ for both), suggesting that the barriers to adoption are systemic and structural rather than demographic.

Qualitative interview data identified three primary explanations for non-adoption: low awareness of the existence of tinnitus-specific apps, uncertainty about which apps to trust in an unregulated marketplace, and experiences of mismatched features that did not address individual symptom profiles. These findings resonate with Mehdi, Stach, et al.'s [18] observation that few apps have scientific backing, and Deshpande and Shimunova's [20] warning that misinformation apps pose hazards to patients seeking reliable digital support. The proliferation of apps without standardised certification or quality benchmarks directly undermines user confidence and adoption.

This non-adoption paradox also carries theoretical implications. Within the SWB framework [24], the potential well-being gains associated with app use, demonstrated through Spearman correlations of $\rho=0.71$ between app use and well-being, are currently inaccessible to the majority of tinnitus sufferers. The desire theory [23] perspective similarly suggests that the unfulfilled desire for symptom relief and improved daily functioning, which motivates help-seeking, is not being channelled towards available digital solutions due to awareness and trust deficits.

Feature Preferences and Evidence-Based Content Gaps

Among active app users, ambient sounds (71.43% useful/very useful) emerged as the most practically valued feature, followed by educational content about tinnitus (64.29%). These findings align with the dominance of sound-based therapeutic approaches in the literature [9,10,35] and reinforce the central role of patient education in tinnitus self-management [36,37]. Notably, the high rates of uncertainty surrounding more advanced features, binaural beats (71.43% unsure), isochronic tones (64.29% unsure), and hypnosis (64.29% unsure), do not necessarily indicate rejection of these features but rather a lack of in-app educational scaffolding to guide their use. This represents a critical design failure: apps incorporate evidence-informed therapeutic modalities without adequately explaining their rationale or mechanism to users.

Qualitative data corroborated this pattern, with participants frequently describing transformative educational moments, understanding why they perceived phantom sounds, learning about habituation, as pivotal to their ability to cope. The implication for app developers is clear: educational content must be integrated not merely as a discrete feature but as a scaffold that contextualises all therapeutic modalities within an accessible, evidence-based framework.

Security, Privacy, and Trust as Adoption Enablers

Across both survey and interview data, security and privacy concerns emerged as critical adoption enablers. Participants consistently rated security dimensions, data protection (85.72%), breach notification (85.71%), and anonymisation (78.57%), as important or very important. These findings reflect broader patterns in mHealth adoption literature [11,38], where data privacy concerns are among the most frequently cited barriers to health app uptake. For tinnitus management apps, which may collect sensitive audiological and psychosocial data, addressing these concerns through transparent data governance, robust authentication mechanisms, and clear breach notification protocols is essential to building the trust required for sustained engagement.

Platform Considerations and User-Centred Design

The significant sentiment disparity between Google Play and iOS platforms suggests that tinnitus app developers cannot apply uniform development and marketing strategies across platforms. The higher negative sentiment on iOS (21.08%) may partly reflect the generally more critical review culture on the Apple platform, but also indicates genuine user experience deficits. Design & UX featured prominently in both positive and negative topic analyses, underscoring the dual role of interface design as both a driver of satisfaction and a source of frustration. The calls for customisation (85.71% important/very important) and multilingual availability (71.43%) further indicate that tinnitus app users constitute a diverse population whose needs cannot be met by generic, one-size-fits-all solutions.

Comparison with Prior Literature

This study's findings both extend and challenge the existing evidence base. While prior systematic reviews [12,13] have documented the therapeutic promise of tinnitus apps, they have predominantly relied on MARS quality assessments without integrating patient-reported outcomes or large-scale sentiment data. The RCT evidence from Yoon et al. [16] and Kutya et al. [17] establishes efficacy under controlled conditions, but the present study's findings indicate that clinical efficacy does not translate into real-world adoption without addressing awareness, trust, and design barriers. This study's integrated mixed-methods approach provides a methodologically more comprehensive evaluation framework that can inform both future research and the development of clinical guidance on recommending apps to tinnitus patients.

Limitations

Several limitations should be noted. First, the sentiment analysis was conducted using Appbot's proprietary NLP algorithms, limiting the transparency and replicability of the pre-classification process. Second, the survey sample (N=171), while purposively diverse, was recruited primarily through online tinnitus support communities and may not fully represent the broader population of tinnitus sufferers, particularly those with lower health literacy or limited internet access. Third, the cross-sectional survey design precludes causal inference regarding the relationship between app use and well-being outcomes. Fourth, the absence of direct non-user perspectives in the interview sample, beyond those inferred through survey data, limits the depth of understanding of non-adoption motivations. Longitudinal research and intervention studies targeting non-adopters are needed to address these gaps.

V. Conclusions

This study provides the most comprehensive mixed-methods evaluation of tinnitus management mobile applications to date. The findings establish that these applications represent genuinely valuable tools for sleep improvement, stress reduction, and patient education, with high positive sentiment (72.38%) and strong correlations between app use and well-being (Spearman $\rho=0.71$). Simultaneously, the 91.4% non-adoption rate exposes a critical systemic failure in reaching those most in need. Closing this efficacy–accessibility gap requires coordinated action across four dimensions:

- Evidence-based development: Apps must integrate clinical validation and provide in-app educational scaffolding for all therapeutic modalities.
- Healthcare integration: Clinicians must be equipped with the knowledge to recommend evidence-based apps as part of structured tinnitus management pathways.
- Regulatory standardisation: App store operators and health authorities should establish minimum quality standards, including mandatory disclosure of evidence-based and data governance practices.
- Personalisation and accessibility: Apps must be designed with user-centred, customisable interfaces that accommodate diverse symptom profiles, literacy levels, and linguistic backgrounds.

When these conditions are met, tinnitus management mobile applications have the potential to transform patient care for millions of individuals worldwide who currently have no effective self-management tools.

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Conflicts of Interest

None declared.

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