Original paper

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Mobile applications for management of tinnitus: users’ survey, quality assessment and content analysis

Abstract

Background: Tinnitus is the perception of a sound without any outside source. It affects 6 million people in the UK. Sound therapy is a core component of many tinnitus management programmes. Potential mechanisms of benefit include making tinnitus less noticeable, habituation, distracting attention from tinnitus, relaxation, and promoting neuroplastic changes within the brain. In recent years there has been a substantial increase in the use of mobile technology. This provided an additional medium via which people with tinnitus can access different tinnitus management options including sound therapy.

Objective: The purpose of this study was to: 1) generate the list of apps that people use for management of their tinnitus; 2) explore reasons for apps use and non-use; 3) perform quality assessment of the most cited apps; 4) perform content analysis to explore and describe options and management techniques available in the most cited apps.
**Methods:** An online survey consisting of 33 open and closed questions captured: i) demographic information about respondents, information about tinnitus, hearing loss; ii) mobile apps specific questions asked about the motivation to use an app to manage tinnitus, the apps which respondents used for managing tinnitus, important factors when choosing an app, devices used to access apps, reasons for not using apps. The quality of the most cited apps listed by respondents was assessed using the Mobile Apps Rating Scale (MARS) Content and features of the most cited apps were analysed.

**Results:** Data from 643 respondents were analysed. The majority of respondents (75%) had never used an app for management of tinnitus mainly due to lack of awareness (79%). The list of the 55 apps that people use for the management of their tinnitus was generated. These included apps which were developed specifically for the management of tinnitus, however the majority of cited apps were developed for other problems (e.g. sleep, depression/anxiety, relaxation). Quality assessment of the 18 most popular apps, using MARS resulted in a range of mean scores from 1.6 to 4.2 (out of 5). In line with the current model of tinnitus management, sound was the main focus of the majority of the apps. Other components included relaxation exercises, elements of cognitive behaviour therapy, information and education and hypnosis.

**Conclusions:** People use apps for the management of their tinnitus, however this was done mostly as a self-help option without conjunction with management provided by hearing healthcare professionals. Further research should consider the place for apps in the tinnitus management (standalone self-management intervention vs part of the management by a hearing professional). As the content of the apps varies in respect to sound options, information and management strategies it seems that the choice of the best management app should be guided by individual patient needs and preferences.

**Keywords:** tinnitus; mobile applications; management; users’ survey; quality assessment; Mobile Apps Rating Scale; content analysis

**Word count:** 7362
Introduction

Tinnitus is the perception of a sound without any outside source. It affects 6 million people in the UK. Sound therapy, in the form of hearing aids or sound generators, is a core component of many tinnitus management programmes. Potential mechanisms of benefit include making tinnitus less noticeable, promoting habituation, distracting attention from tinnitus, relaxation, and promoting neuroplastic changes within the auditory system. Sound therapy can be provided by a range of media including hearing aids, wearable sound generators, combination hearing aids or bedside/table-top sound generators [1]

Mobile technology including smartphones provide an additional medium via which people with tinnitus can access different tinnitus management options including sound therapy. Recent years have seen a substantial increase in the use of mobile technology. According to the recent Global Mobile Consumer Survey by Deloitte 85% of adults in the UK own a smartphone and this number is expected to increase to 90% by 2020. Over 37 million 16-75 year olds use their device every day and 34% look at their device within five minutes of waking [2]

The use of mobile applications to deliver healthcare (M-Health) has several advantages including: 1) improved access to healthcare; 2) improved quality of healthcare; and 3) lowering the cost of healthcare [3] There are also potential issues associated with M-Health and these include safety or misuse [4]; quality and effectiveness [5] [6]; responsibility and risk [7] The attitudes of patients and healthcare professionals towards these new developments also needs to be assessed and addressed [8]

The quality and functionality of healthcare apps, including tinnitus apps can vary greatly. The IMS Institute for Healthcare Informatics [9] assessed the functionality of 16,275 healthcare apps according to 25 individual criteria including: the type and quantity of information provided by the app, how the app tracks or captures user data, the communication processes utilised by the app, and the quantity of device capabilities included in the app. More than 90% of the apps tested received a score of 40 or less out of possible 100 which indicates the general low quality of the apps tested

In 2013 the NHS Commissioning Board created a Digital Apps Library for healthcare apps. Currently in the early version of the library there are 42 apps listed that ‘meet the high standard of quality, safety and effectiveness’ [10] Some apps were tested further to assure they meet NHS standards for
clinical effectiveness, safety, usability and accessibility. While the library includes apps developed for variety of healthcare conditions as well as healthy living in general it does not currently list apps for management of tinnitus. However, people with tinnitus might find some of the apps helpful, such as for example those developed for management of stress and anxiety.

To date no research has looked specifically at the use of mobile apps for tinnitus management. A study by Paglialonga and colleagues [11] identified and assessed apps for hearing science and care in general which were available on the leading platforms (iOS, Android, Windows Phone stores). Tinnitus apps identified by the authors were mentioned in two categories: 1) screening and assessment (estimation of tinnitus pitch and loudness) and 2) intervention and rehabilitation (tinnitus management tools such as maskers and sound stimulation). The identified apps were intended to be used either by hearing healthcare professionals, people with tinnitus, or both.

Despite the increasing popularity of apps in general it is unclear what proportion of people use apps for tinnitus management and which apps are the most popular. The purpose of this study was to: 1) generate the list of apps that people use for management of their tinnitus; 2) explore reasons for apps use and non-use; 3) perform quality assessment of the most cited apps; 4) perform content analysis to explore and describe options and management techniques available in these most cited apps.

**Methods**

**Online survey**

The CHERRIES checklist was used to report the methods and results for the survey [12] Ethics approval for the study was granted by the University of Nottingham Faculty of Medicine & Health Sciences Research Ethics Committee ref no. LT18082016. As this was an anonymous online survey completion of the survey was taken as informed consent. No identifiable data were collected.

**Survey development**

Items for the survey were decided through an iterative process. A list of questions was generated to capture: i) demographic information about respondents (gender, age group, country of residence), information about tinnitus (presence, duration, and severity), hearing loss (presence, severity, use of devices to address hearing loss); ii) mobile apps specific questions asked about motivation to use an app to manage tinnitus, a list of apps respondents used for managing tinnitus, important factors when choosing an app, devices used to access apps, reasons for not using apps to manage tinnitus.
First, questions were generated in collaboration with British Tinnitus Association (BTA) and based on information about the apps that patients are seeking when contacting the BTA. Second, questions were generated to capture information missing from the general tinnitus literature (e.g. factors that drive the decision to try apps or factors important when choosing apps for tinnitus management). Questions were first drafted by one of the authors (MS) and then appraised and reduced by other co-authors towards strong face validity and relative merit of the included items. The final questionnaire included 33 items presented on 15 pages. The final survey comprised a mix of open and closed questions and took between 15 and 30 minutes to complete. The survey used skip logic depending if a participant had used/not used apps for tinnitus management before or had/did not have tinnitus. No randomisation of items was used. All question, with exception of questions asking about additional comments, were mandatory. Respondents were unable to change their responses once submitted.

Administration
Over a 2-month period, people were invited to take part in an anonymous online survey which was hosted on Survey Monkey©. Responses were collected between 15 August 2016 and 15 November 2016. The survey was open to anyone who wanted to take part and both app users and non-users were invited. The survey was advertised via email to current British Tinnitus Association (BTA) members and NIHR Nottingham Biomedical Research Centre (BRC) participants’ database members. The link to the questionnaire was sent out using social media to people following the BTA and BRC via Facebook and Twitter. Only one submission from each IP address was permitted by the survey software.

Analysis
Closed questions were analysed in IBM’s SPSS Statistics 24 using descriptive statistics, including frequencies, means and standard deviations. Patterns of use depending on age, tinnitus severity and duration, hearing loss and gender were analysed using chi square statistics. Qualitative data from the open questions were analysed separately using inductive thematic analysis (Braun & Clarke, 2006).

Quality Assessment of the apps
The quality of the most cited apps listed by respondents was assessed using the Mobile Apps Rating Scale [13]. To be included in the quality assessment an app needed to be cited by 2 or more people. The MARS scale was developed to be a simple, objective and reliable tool for assessing the quality of mobile health apps. It contains 23 items rated on a 5-point scale (1- inadequate, 2-poor, 3-
acceptable, 4-good, 5-excellent) or not applicable. Nineteen questions form the objective quality section which is divided into 4 scales: engagement, functionality, aesthetics, and information quality. Four questions form the subjective quality section evaluating users’ satisfaction. Each app was scored independently by three researchers (MS, SS, KN, or DS) using MARS. Apps were tested on Android and iPhone devices where the app was available on both devices. This was followed by a consensus meeting where the scores and reasons for them where discussed. Consensus on the final scoring was then reached by all three raters for the objective scales. For the subjective scale an average rating was taken.

Content and features analysis
Content and features of the most cited apps were analysed using a bottom-up approach. MS developed a coding manual based on the features listed in the online description of the apps in the Apple App Store, Google Play and the Amazon App Store, including descriptions and example quotes from the text. The coding manual was reviewed by MS and SS to assure clarity of definitions and examples. A small sample of the cited apps were then assessed by MS and any missing codes generated were added to the coding manual. This coding manual was then used to identify the content and features of the most cited apps. MS and SS independently applied the coding manual to each mobile app to clarify ambiguous codes, remove duplicate codes, and identify data that did not fit the coding scheme. Coding was then compared and discussed between coders and subsequent modifications made to the coding manual, resulting in final version of the manual (Multimedia Appendix 1).

Results
Six hundred and seventy five people responded to the survey. Responses were collected between 15 August 2016 and 15 November 2016. From 675 participants who read the welcome page and proceeded to consenting, 671 consented to take part in the survey, which gives 99.6% participation rate. The data were included in the analysis if the respondents provided a response to the question if they had ever used an app to manage their tinnitus, which left 643 responses for further analysis. Thirty two people provided only initial demographic information, therefore were excluded from the analysis.

From 643 respondents 158 respondents had used an app and 485 had never used an app to manage their tinnitus. The majority of participants were UK residents (n=627; 97.5%), with 16 residents from
other countries including Australia (n=5), Canada (n=4), Norway (n=2), Cyprus (n=1), Denmark (n=1), Egypt (n=1), Ireland (n=1) and Malaysia (n=1).

**Demographic data**
The majority of respondents (n=637) had tinnitus at the point of completing the survey and six had tinnitus in the past. The largest group of respondents were people who had tinnitus for over 10 years (n=299, 46.5%) (Figure 1). There was a significant association between tinnitus duration and use or non-use of apps, $x^2=44.81$, $p<0.001$. Among the users there were significantly more people in '6 months-1 year' $(z=3.0)$ and '2-5 years' $(z=3.2)$ groups and significantly less users in 'over 10 years' group $(z=-3.6)$. Among the non-users there were significantly more people in the over '10 years group' $(z=2.0)$.

*Figure 1. Tinnitus duration in all respondents (black bars), app users (grey bars) and non-users (white bars).*

The majority of respondents (n=278, 43.2%) reported their tinnitus to be severe, while 33 reported slight, 151 mild and 181 severe tinnitus. For the $x^2$ analysis of tinnitus severity in app users and non-
users we have combined 'slight' and 'mild' categories to achieve at least 5 observations in each category. There was a significant association between tinnitus severity distribution and use or non-use of apps, $x^2(2) = 11.3$, $p = 0.004$. Among users there was significantly less people who reported slight/mild tinnitus ($z = -2.8$).

The age range of survey respondents was from under 18 to 75 and over years with largest representation from people aged 55-64 years (31.7%) and 65-74 years (31.7%) (Figure 2). The majority of survey respondents were people with tinnitus therefore such age distribution is in line with the data showing higher prevalence of tinnitus with age [14] There was a significant association between the age distribution and use or non-use of apps, $x^2(7) = 40.9$, $p < 0.001$. Among the users there was significantly more people in 45-54 years group ($z = 3.2$) and significantly less in 65-74 (-2.7) and over 75 years ($z = -2.8$) groups.

Figure 2. Age distribution for all respondents (black bars), app users (grey bars) and non-users (white bars).

From 643 respondents 289 were female (45%), 350 were male (54.4%), and four identified in another way (0.6%). The proportion of males vs females was similar amongst app users (53/47%) and non-users (55/45%), $x^2(1) = 0.43$, $p = 0.51$. 
The majority of respondents reported some degree of hearing loss (494, 76.8%), consistent with the association between tinnitus and hearing loss [15]; [16]. The largest group of respondents reported mild hearing loss (n=261, 40.6%), with 149 respondents reporting no hearing loss (23.2%), 172 moderate (26.8%) and 61 severe/profound hearing loss (9.5%). There was a significant association between the degree of hearing loss distribution and use or non-use of apps, \( x^2(3)=17.5, p=0.001 \). There was significantly less app users in the severe/profound hearing loss group \( z=-2.3 \).

Out of 494 respondents with hearing loss 263 reported wearing hearing aids and 13 reported wearing cochlear implants. Fifty six hearing aid users and only two cochlear implant users reported using apps to manage their tinnitus. Fifty nine respondents reported using assistive listening devices and 19 of those reported using apps.

**Apps that people tried for tinnitus management**

Altogether 120 respondents listed 55 apps that they have tried to manage their tinnitus. In addition fifteen people listed apps with a more general context such as radio, You Tube, podcast apps and audiobook apps without specifying the exact content that they are using to manage their tinnitus. As there was no way of verifying which content have been used those were excluded from further analysis. A full list of the 55 apps listed by respondents and their characteristics is available in Appendix 2.

Six main components of the apps have been identified based on the description in the app stores (Apple, Google, Amazon): i) Sound generation/therapy, ii) Meditation and mindfulness, iii) Information and education, iv) Hypnosis, v) Relaxation exercises, and vi) Assessment (Fig.3). In 70% of listed apps sound was the main focus of the app including providing a selection of ambient sounds, sound enrichment, sounds for masking distracting sounds or tinnitus, notched music, binaural beats or isochronic tones and sound-based training. Eleven percent of apps included guided meditation and mindfulness techniques. Six percent of apps had an extensive information and education component and included sound level meters, apps containing information about tinnitus, information about sound therapy, and counselling. Hypnosis for tinnitus or for other problems was a focus of 5% of apps. Relaxation exercises such as breathing exercises and muscle relaxation were the component of 5% of apps. Three percent of apps focused on assessment, including measuring tinnitus frequency and assessment for Tinnitus Retraining Therapy.
From 55 listed apps fourteen were developed specifically for tinnitus (Multimedia Appendix 1). Six apps used sound or sound therapy to provide relief or distraction from tinnitus (e.g. Tinnitus Therapy Lite, Sound Relief, Tinnitus Therapy Tunes), three provided a combination of sound and relaxation exercises (Beltone Tinnitus Calmer, ReSound Relief), three implemented specific tinnitus management programmes - Tinnitus Retraining Therapy (TRT, iTinnitus), Progressive Tinnitus Management (PTM, Tinnitus Balance), Zen Therapy (Widex Zen, Tinnitus Management), one indicated it was a combination of informational resource and sound therapy (Starkey Relax), one used hypnosis (Overcome Tinnitus) and one aimed to measure tinnitus pitch (Tinnitus Measurer). Five apps were not developed specifically for tinnitus but mentioned tinnitus as one of the possible applications either through masking or without specifying specific mechanism through which the app might be helpful for tinnitus. Thirty two apps were developed for sleep, relaxation, concentration, meditation, stress, anxiety, and general well-being and have not mentioned tinnitus as a potential application of the app. Two apps were sound level meters.
Each app was listed by between 1 and 21 respondents. The apps that were the most often listed by respondents as the ones they have tried for managing their tinnitus were *White Noise Free* (n=21), *Oticon Tinnitus Sound* (n=13), *Relax Melodies: Sleep Sounds* (n=10), *myNoise* (n=7) and *Tinnitus Therapy Lite* (n=7).

Given that the majority of the apps (n=37) were only mentioned by one respondent we performed a further analysis for those eighteen apps that were listed by at least two people (Table 1). This included quality assessment using MARS [12] and detailed content analysis.

### Table 1. Characteristics of the apps mentioned by at least two respondents (N=number of times app was cited)

<table>
<thead>
<tr>
<th>Name</th>
<th>Developer</th>
<th>Category</th>
<th>Star rating*</th>
<th>Cost GBR £</th>
<th>In app purchases</th>
<th>Installs *</th>
<th>Platform and version</th>
<th>Last update</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>White Noise Free</strong></td>
<td>TMSOFT</td>
<td>Health &amp; Fitness</td>
<td>4.5</td>
<td>Free</td>
<td>No</td>
<td>1-5 million</td>
<td>Apple (7.0), Google (Varies with device) &amp; Amazon (7.2.3)</td>
<td>2016</td>
<td>21</td>
</tr>
<tr>
<td><strong>Oticon Tinnitus Sound</strong></td>
<td>Oticon A/S</td>
<td>Medical</td>
<td>4.2</td>
<td>Free</td>
<td>No</td>
<td>50-100k</td>
<td>Apple (1.0.2) &amp; Google (1.0.1)</td>
<td>2015</td>
<td>13</td>
</tr>
<tr>
<td><strong>Relax Melodies: Sleep Sounds</strong></td>
<td>Ipnos Software</td>
<td>Health &amp; Fitness</td>
<td>4.7</td>
<td>Free</td>
<td>Yes</td>
<td>5-10 million</td>
<td>Apple (6.2), Google (Varies with device) &amp; Amazon (6.1.2)</td>
<td>2017</td>
<td>10</td>
</tr>
<tr>
<td><strong>myNoise</strong></td>
<td>myNoise BVBA</td>
<td>Health &amp; Fitness</td>
<td>4.5</td>
<td>Free</td>
<td>Yes</td>
<td>50-100k</td>
<td>Apple (2.4.2) &amp; Google (1.2)</td>
<td>2017</td>
<td>7</td>
</tr>
<tr>
<td><strong>Tinnitus Therapy Lite</strong></td>
<td>Sound Oasis</td>
<td>Health &amp; Fitness</td>
<td>4.5</td>
<td>Free sample of 5 sounds and basic options</td>
<td>No Pro version available</td>
<td>10-50k</td>
<td>Apple (1.1.6), Google (1.1.6) &amp; Amazon (1.0.3)</td>
<td>2017</td>
<td>7</td>
</tr>
<tr>
<td><strong>Headspace: Guided Meditation</strong></td>
<td>Headspace, Inc.</td>
<td>Health &amp; Fitness</td>
<td>3.9</td>
<td>Free sample of 10 day</td>
<td>No Pro version available</td>
<td>1-5 million</td>
<td>Apple (3.4.0), Google (3.1.2)</td>
<td>2017</td>
<td>6</td>
</tr>
<tr>
<td>App Name</td>
<td>Developer/Publisher</td>
<td>Category</td>
<td>Mediation Rating</td>
<td>Price Model</td>
<td>App Compatibility</td>
<td>Number of Installs</td>
<td>Average Star Rating</td>
<td>Year</td>
<td>Version</td>
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<tr>
<td>Mindfulness</td>
<td></td>
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</tr>
<tr>
<td>Sleep Bug: White Noise Soundscape &amp; Music Box</td>
<td>Panzertax</td>
<td>Health &amp; Fitness</td>
<td>4.4</td>
<td>Free</td>
<td>Yes</td>
<td>100-500k</td>
<td>Apple (3.4) &amp; Google (1.6)</td>
<td>2017</td>
<td>6</td>
</tr>
<tr>
<td>Tinnitus Calmer</td>
<td>Beltone</td>
<td>Medical</td>
<td>4.3</td>
<td>Free</td>
<td>No</td>
<td>10-50k</td>
<td>Apple (3.4.2) &amp; Google (3.1.4)</td>
<td>2017</td>
<td>4</td>
</tr>
<tr>
<td>Sleep Pillow</td>
<td>FITNESS22 LTD</td>
<td>Health &amp; Fitness</td>
<td>4.8</td>
<td>Free</td>
<td>Yes</td>
<td>100-500k</td>
<td>Apple (7.4) &amp; Google (4.3)</td>
<td>2016</td>
<td>4</td>
</tr>
<tr>
<td>Soothing Sounds Lite</td>
<td>Lost Ego Studios Limited</td>
<td>Apple: Medical; Google: Lifestyle</td>
<td>3.5</td>
<td>Free</td>
<td>No</td>
<td>1-5k</td>
<td>Apple (1.22) &amp; Google (1.0)</td>
<td>2017</td>
<td>4</td>
</tr>
<tr>
<td>Tinnitus Aid: Nature sounds to mask ear ringing</td>
<td>Phase4 Mobile</td>
<td>Medical</td>
<td>NA</td>
<td>Free</td>
<td>No</td>
<td>NA</td>
<td>Apple (1.3)</td>
<td>2016</td>
<td>3</td>
</tr>
<tr>
<td>Tinnitus Balance</td>
<td>Phonak</td>
<td>Medical</td>
<td>3.7</td>
<td>Free</td>
<td>No</td>
<td>50-100k</td>
<td>Apple (2.1) &amp; Google (1.1.947)</td>
<td>2016</td>
<td>3</td>
</tr>
<tr>
<td>Rain Rain Sleep Sounds</td>
<td>Tim Gostony</td>
<td>Health &amp; Fitness</td>
<td>4.7</td>
<td>Free</td>
<td>Yes</td>
<td>100-500k</td>
<td>Apple (5.2), Google (4.1) &amp; Amazon (3.4)</td>
<td>2017</td>
<td>3</td>
</tr>
<tr>
<td>Nature Sounds</td>
<td>Relaxio</td>
<td>Health &amp; Fitness</td>
<td>4.7</td>
<td>Free</td>
<td>Yes</td>
<td>1-5 million</td>
<td>Google (2.9.3)</td>
<td>2016</td>
<td>2</td>
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<tr>
<td>Relax Noise 3</td>
<td>Martin Nathansen</td>
<td>Health &amp; Fitness</td>
<td>3.95</td>
<td>Free</td>
<td>No</td>
<td>100-500k</td>
<td>Google (1.6) &amp; Amazon (1.6)</td>
<td>2015</td>
<td>2</td>
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<tr>
<td>ReSound Relief</td>
<td>GN ReSound A/S</td>
<td>Medical</td>
<td>4</td>
<td>Free</td>
<td>No</td>
<td>10-50k</td>
<td>Apple (3.1.5) &amp; Google (3.1.4)</td>
<td>2017</td>
<td>2</td>
</tr>
<tr>
<td>Sleep Well Hypnosis</td>
<td>Surf City Apps LLC</td>
<td>Health &amp; Fitness</td>
<td>3.8</td>
<td>Free</td>
<td>Yes</td>
<td>100-500k</td>
<td>Apple (3.9), Google (2.14.4) &amp; Amazon (2.12)</td>
<td>2017</td>
<td>2</td>
</tr>
<tr>
<td>Zenways</td>
<td>Wimbledon Sound</td>
<td>Lifestyle</td>
<td>NA</td>
<td>Free</td>
<td>No</td>
<td>NA</td>
<td>Apple (1.1)</td>
<td>2013</td>
<td>2</td>
</tr>
</tbody>
</table>

*Average star rating across platforms
*Data on number of installs were available only on Google Play
Reasons for non-use
The most commonly listed reason for not using apps for management of tinnitus was lack of awareness of apps (79%). Twenty percent of respondents declared that they did not use apps as they were not good with technology, 10% could not find an app that they thought would be helpful for their tinnitus, 9% said that they did not have mobile phone or tablet, 3.7% had only a basic phone that did not support apps or problems with their phone, 2.4% did not need to use apps, 2.2% did not think the apps would help with their tinnitus and 2% used other technology such as a bedside sound generator or cd player. Other reasons (<1%) for app non-use included hearing problems, wanting a cure rather than management option, lack of knowledge about which apps could help, not wanting to rely on technology, not wanting to pay attention to tinnitus, apps exacerbating tinnitus, hyperacusis, preference for a personal contact, too many apps to choose from, having tinnitus for a short period of time, or lack of interest in apps.

Motivation to try an app
Twenty two percent of respondents tried an app to address sleep problems including getting to sleep and staying asleep, 20% hoped to achieve masking of their tinnitus, while 19% followed a recommendation from either a hearing professional, family member, or people online. Eighteen percent tried an app to achieve more general goals such as: tinnitus relief, find ways of managing their tinnitus, help with tinnitus and coping with tinnitus, without specifying ways or mechanisms through which that could be achieved. For nine percent of respondents the motivator to try an app was desperation and frustration due to tinnitus, nine percent were looking for a source of sound generation and sound enrichment. Seven percent of respondents reported that they had tried an app because of the convenience (i.e. when they travel due to portability) and six percent looked for an alternative to other technologies such as CDs, radio, pillow speakers or combination aids. Other motivators for trying an app (<5%) included: achieving tinnitus reduction/alleviation, distraction, relaxation, reducing stress/anxiety, having an option to stream via hearing aid, variety/choice of sounds in the app, curiosity, free trial of an app, and aiding habituation.

Important factors when choosing an app
Ease of use (72.5%), followed by trustworthy source (44.2%), reviews (39.2%) and cost (39.2%) were most commonly listed as important factors when choosing an app. Additional factors included recommendation by a medical professional (25.8%), recommendation by another person with tinnitus (18.3%), and recommendation by friend/family (5.8%), followed by name of an app (3.3%).
MARS App Quality Scores
Three raters rated the apps and reliability of objective scales calculated as Cronbach’s α before consensus was 0.76. Consensus was reached on all the ratings for all the rated apps. Table 2 presents final scores for the four subscales (engagement, functionality, aesthetics, and information), overall quality score (mean of four subscales) and subjective quality score (satisfaction) for the 18 apps that at least two respondents listed as those that they have tried for management of their tinnitus. Overall the average MARS quality scores for 18 apps mentioned by at least two respondents varied from 1.5 to 4.2 (out of 5) with scores for individual subscales varying from 1 to 4.6, Table 2. Subjective scores varied from 1 to 4.1. Of the four subscales functionality had the highest median score (4.4) and aesthetics had the lowest median score (3.15). The White Noise Free app had the highest overall MARS score (4.2), followed by Relax Melodies (4.1), Headspace (4.1), Oticon Tinnitus Sound (3.9), and Sleep Pillow (3.9). All but two apps (Soothing Sounds Lite and Sleep well Hypnosis) met or exceeded the minimum acceptability score of 3.0.

Table 2. The Mobile App Rating Scale mean scores for 18 most cited apps

<table>
<thead>
<tr>
<th></th>
<th>Engagement</th>
<th>Functionality</th>
<th>Aesthetics</th>
<th>Information</th>
<th>Mean</th>
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</tr>
</thead>
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<tr>
<td>White Noise Free</td>
<td>4.2</td>
<td>4.5</td>
<td>4.3</td>
<td>3.7</td>
<td>4.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Oticon Tinnitus Sound</td>
<td>3.6</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Relax Melodies</td>
<td>4.4</td>
<td>4.5</td>
<td>3.3</td>
<td>4.2</td>
<td>4.1</td>
<td>4</td>
</tr>
<tr>
<td>myNoise</td>
<td>3.8</td>
<td>3.25</td>
<td>3</td>
<td>3</td>
<td>3.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Tinnitus Therapy Lite</td>
<td>2.2</td>
<td>5</td>
<td>3.3</td>
<td>2.6</td>
<td>3.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Headspace</td>
<td>4.6</td>
<td>4.5</td>
<td>3.3</td>
<td>4.2</td>
<td>4.1</td>
<td>4.1</td>
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<tr>
<td>Sleep Bug</td>
<td>3.4</td>
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<td>3.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Beltone Tinnitus Calmer</td>
<td>4.6</td>
<td>3.8</td>
<td>3</td>
<td>3.6</td>
<td>3.8</td>
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</tr>
<tr>
<td>Sleep Pillow</td>
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<td>3.3</td>
<td>3.9</td>
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<tr>
<td>Soothing Sounds Lite</td>
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<td>1.7</td>
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<td>1</td>
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<tr>
<td>Tinnitus HQ</td>
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<td>2.7</td>
<td>3.3</td>
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<tr>
<td>Tinnitus</td>
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<td>4</td>
<td>2.7</td>
<td>3</td>
<td>3.2</td>
<td>2.3</td>
</tr>
</tbody>
</table>
The characteristics of the eighteen most often mentioned apps (listed by at least two respondents) are summarised in Table x. Those included six apps developed specifically for tinnitus (Beltone Tinnitus Calmer, Oticon Tinnitus Sound, ReSound Relief, Tinnitus Aid, Tinnitus Balance and Tinnitus Therapy Lite), four apps that were developed for other problems but mentioned tinnitus as one of the possible applications (myNoise, Relax Noise 3, Soothing Sounds, and White Noise Free) and eight apps that were developed for other problems and did not mention tinnitus (Nature Sounds, Rain Rain Sleep Sounds, Relaxed Melodies, Headspace, Sleep Bug, Sleep Pillow, Soothing Sounds Lite, and Sleep Well Hypnosis). Beltone Tinnitus Calmer, Oticon Tinnitus Sound, ReSound Relief and Tinnitus Balance were developed by hearing aid manufacturers and included an information that they should be used as a part of a tinnitus management plan provided by hearing care professional.

The tinnitus-specific goals listed by the apps included masking tinnitus (myNoise, Relax Noise 3, Tinnitus Therapy Lite, and White Noise Free), decreasing the annoyance of tinnitus (Oticon Tinnitus Sound), providing temporary relief from tinnitus (Oticon Tinnitus Sound), shift attention away/distracting from tinnitus (Beltone Tinnitus Calmer, Oticon Tinnitus Sound, ReSound Relief), managing tinnitus using sound therapy (Tinnitus Therapy Lite), helping prevent problems associated with tinnitus (Soothing Sounds Lite), ease the problems associated with tinnitus (Soothing Sounds), and relieving tinnitus symptoms (Tinnitus Aid).

Apps that were not developed specifically for tinnitus but mainly for other problems usually listed multiple goals. Nine apps addressed sleep problems, including falling and staying asleep, insomnia, and improving quality of sleep (myNoise, Nature Sounds, Rain Rain Sleep Sounds, Relax Melodies,
Sleep Bug, Sleep Pillow, Sleep Well Hypnosis, Soothing Sounds, White Noise Free). Seven app listed relaxation (Rain Rain Sleep Sounds, Relax Melodies, Sleep Well Hypnosis, Soothing Sounds, White Noise Free) and five reducing stress or anxiety as one of the goals (myNoise, Relax Melodies, Sleep Well Hypnosis, Soothing Sounds, White Noise Free). Five apps included the aim to block distractions/background noises or mask interruptions or noises one disliked (myNoise, Relax Noise 3, Sleep Bug, Soothing Sounds, White Noise Free). Three apps listed increasing focus or improving concentration (myNoise, Sleep Bug, White Noise Free). Two of the apps aimed to enhance/increase privacy (Sleep Bug, White Noise Free). Other listed aims included pacifying fussy and crying babies (White Noise Free), soothing headaches and migraines (White Noise Free), living a healthier, happier, more enjoyable life (Headspace), and helping calm a busy mind (Sleep Bug).

All of the eighteen apps had a free version available, however Headspace and Tinnitus Therapy Lite had only a limited demonstration of meditations/sounds available for free with an option to purchase the pro version. The Tinnitus Aid app was a free version of the Tinnitus HQ app with more sounds to choose from and more filters available in the pro version. Seven apps had in app purchases which allowed the purchase of a larger selection of sounds and of unlocking more advanced options.

Sixteen apps were updated in 2016 or 2017 with Zenways last updated in 2013 and Relax Noise 3 in 2015. The number of installs ranged from 1-5k (Soothing Sounds Lite) to 5-10 million (Relax Melodies). The majority of the apps were classified in the Health & Fitness category (n=11), with five apps in the Medical category (Beltone Tinnitus Calmer, Oticon Tinnitus Sound, ReSound Relief, Tinnitus Aid, Tinnitus Balance), one in Lifestyle (Zenways) and one classified as Medical in the App store and as Lifestyle in Google store. Oticon Tinnitus Sound was the only app stating an age limit which was over 17

Content and features of the apps
Detailed content analysis was conducted for those 18 apps that at least two respondents listed as those they have tried to manage their tinnitus.

Sound
All but two apps (n=16) featured sound generation or sound therapy. Sound generation features included a wide selection of sounds. One app offered the possibility to record and loop your own sounds (White Noise Free), seven offered an option to import/download additional sounds for free (Beltone Tinnitus Calmer, myNoise, ReSound Relief, White Noise Free) or purchase sounds (Sleep
Pillow) from the app library or your own library (Oticon Tinnitus Sound, Tinnitus Balance). The White Noise Free app linked to the White Noise Market app for even more choice of sounds to download.

All sixteen apps featured volume control for the sounds. Six apps allowed adjustments beyond volume control, such as adjusting sound balance (Beltone Tinnitus Calmer, ReSound Relief, White Noise Free), pitch (White Noise Free), frequency shaping (my Noise, Tinnitus Aid), variance (White Noise Free), speed (White Noise Free), intensity (e.g. a small log fire to a roaring beach fire; Soothing Sounds Lite). myNoise had a range of frequency shaping options such as animating sounds (i.e. zen, subtle, moderate, allegro, wobbler), setting colour of the sound (brown, grey, pink, white), setting frequency bandwidth (e.g. centred around specific frequency) and scene (e.g. dark rain, fairy rain, under the leaves for Rain Noise). Fifteen apps offered endless sounds, with three apps using an option to loop sounds (Relax Melodies, Tinnitus Balance, White Noise Free) and Soothing Sounds claiming they were using an advanced soundscape generator which does not loop sounds but generates them in a way that one would not hear the same 10 seconds of sound. In addition Relax Melodies featured a loop correction option which allowed the user to try other modes in case the pause could be heard in the looped sounds. The remaining twelve apps have not specified how they have achieved the endless sound. Tinnitus Aid offered ‘long high-quality recordings’.

Nine apps included the possibility to mix different sounds to create personalised ‘soundscapes’ with all of those apps allowing to adjust the volume of the sounds individually and some of the apps allowing to adjust balance (Beltone Tinnitus Calmer, ReSound Relief, White Noise Free) and pitch of individual sounds in the mix (White Noise Free). Two apps allowed users to add random sound effects to the sounds (Nature Sounds, Sleep Bug). myNoise had an option to mix sound available only on iPhone.

Five apps allowed to rate or mark the favourite sounds and store them in the favourite folder. Four apps (Beltone Tinnitus Calmer, Oticon Tinnitus Sound, ReSound Relief, Tinnitus Balance) allowed the user to create a personalised sound plan and organise the sounds according to sound type (e.g. soothing, interesting or background; (Beltone Tinnitus Calmer, Oticon Tinnitus Sound, Tinnitus Balance, ReSound Relief) or according to situations when a particular sound/s are preferred (Oticon Tinnitus Sound, Tinnitus Balance).

Four apps included binaural beats or isochronic tones in the free versions (myNoise, Relax Melodies, Soothing Sounds, Zenways). Relax Melodies offered six different frequencies, between 2.5 and 20 Hz, of binaural beats which can affect the brain in different ways. For example the description in the
app suggests that 2.5 Hz delta wave 'helps you reach the deepest portion of your sleep cycle', while
10 Hz mid alpha wave 'helps to calm and relax your mind after you have been active'. myNoise
includes 'Binaural Beat Machine' with ten carriers between 1 and 32 Hz to induce a particular
mental state (e.g. deep sleep, relaxed, conscious, focused). Soothing Sounds Lite contained binaural
sounds to 'help improve concentration as well as relaxation' with a slider to adjust tones' frequency.

Twelve apps had a feature to play sound in the background while using other apps (Beltone Tinnitus
Calmer, myNoise, Oticon Tinnitus Sound, Rain Rain Sleep Sounds, Relax Melodies, Relax Noise 3,
ReSound Relief, Sleep Bug, Sleep Pillow, Tinnitus Aid, Tinnitus Balance, Zenways).

Tinnitus Balance app used sound in the context of specific management programme – Progressive
Tinnitus Management.

Meditation and mindfulness
Five apps featured Meditation and mindfulness (Beltone Tinnitus Calmer, Headspace, Relax
Melodies, ReSound Relief, Zenways) with all five featuring guided meditation and two using imagery
(Beltone Tinnitus Calmer, ReSound Relief). In two of the apps meditation and mindfulness was the
main focus of the app (Headspace, Zenways) while in three it was one of the features alongside
other components.

Relax Melodies offered guided meditation programmes and single sessions to help sleep. Beltone
Tinnitus Calmer and ReSound Relief offered six guided meditation sessions to practice techniques for
managing stress and tension caused by tinnitus. Headspace offered a wide selection of themed
meditations on variety of topics (e.g. depression, self-esteem, stress, cancer, sleep, pregnancy,
anxiety), however it is worth noting that the only free option is a ten day meditation programme
that ‘taught you the essentials of living a healthier, happier life’. Zenways offers mindfulness of the
breath meditation to ‘help relax and find your Zen’.

Relaxation exercises
Three apps included relaxation exercises (Beltone Tinnitus Calmer, Oticon Tinnitus Sound, ReSound
Relief) alongside other components. All three apps had breathing exercises, where the task was to
breathe in sync with expanding and collapsing bauble in the screen, together with the voice asking
you to breathe in and breathe out. There was also an option to set the tempo of the breathing as
deep, slow or normal in Beltone Tinnitus Calmer and ReSound Relief and number of breaths per
minute in Oticon Tinnitus Sound. Oticon Tinnitus Sound also featured muscle relaxation which asks
to tense and relax certain group of muscles according to spoken instructions. As all three apps
containing relaxation exercises were apps developed specifically for tinnitus the aim of the
relaxation was to counteract tension and stress caused by tinnitus and in return notice tinnitus less.

Elements of cognitive behaviour therapy (CBT)
Two apps included elements of CBT (Beltone Tinnitus Calmer, ReSound Relief). One of those was
changing unpleasant thoughts about tinnitus into something less upsetting including lack of help,
tinnitus ruining life, loud tinnitus/bad day, lack of support from partner, tinnitus getting worse, lack
of understanding. The second CBT element was pleasant activities, where the user is asked to
nominate activities they would like to do such as meet a friend for tea, learn a new skill, or play
music and receive weekly reminders to do them on the basis that doing things they enjoy makes life
with tinnitus easier.

Information and education
Information and education within the apps included information about tinnitus, using sound for the
management of tinnitus including binaural beats, sleep hygiene, insomnia and its causes,
meditation and mindfulness. Beltone Tinnitus Calmer and ReSound Relief apps provided information
about tinnitus. The apps included the separate section entitled ‘What is tinnitus?’ covering such
topics as how tinnitus is defined, prevalence of tinnitus, causes of tinnitus, what can be done, how
to live with tinnitus, and common therapies. Tinnitus Balance app contains brief information
regarding the prevalence of tinnitus. Five apps contained information about using sound for
management for tinnitus. Beltone Tinnitus Calmer, Oticon Tinntus Sound, ReSound Relief, and
Tinnitus Balance explain the different role that soothing, interesting and background sounds can
play in the management of tinnitus. Tinnitus Therapy Lite contained a description of their tinnitus
relief sounds. Beltone Tinnitus Calmer and ReSoud Relief offered information about sleep hygiene
including sections on eating and drinking, relaxing before bedtime, sleep behaviour, sleeping
environment and timing. Sleep Well Hypnosis included a spoken introduction at the beginning of the
hypnosis session explaining what is insomnia and possible causes of insomnia. Relax Melodies app
described the role of different frequencies of binaural beats from 2.5 to 20Hz. myNoise included an
explanation of what binaural beats do, but this was only available on the iPhone. The Headspace
app had a link to a short video explaining what mediation and mind training is.

Seven apps had weblinks to more information or app help and troubleshooting. Tinnitus Therapy
Lite included link to Sound Oasis® website including more information on tinnitus and how sound
therapy can help. Beltone Tinnitus Calmer and ReSound Relief included link to the ReSound GN
website with information about their hearing and tinnitus products, links to national tinnitus charities and associations, treatment centres and information resources about tinnitus management options. *Sleep Well Hypnosis* included link to answers to ‘hypnosis questions’ such as ‘how long will it take to notice changes’, ‘how does hypnosis work’, and ‘will I lose control while I am under hypnosis’. *myNoise* had a link to *myNoise* on the web with detailed information about noise generators, their calibration, extensive sounds library, and using noise for different purposes (at the office, studying, tinnitus, hyperacusis, relaxation etc.). *Relax Noise 3* had a link to the *Relaxed Noise* 3 website with information about the three different types of noises used in the app: white, pink and red, using those sounds to aid concentration, as tinnitus maskers/noisers, for meditation and as a sleeping aid. *Sleep Well Hypnosis* app features Sleep Booster with binaural beats ‘to induce your brainwave frequency into an optimal state for deep, restorative sleep’, however that option is only available in the pro version of the app. Six apps included a help section or brief introduction to an app within the app (available offline).

**Hypnosis**
*Sleep Well Hypnosis* features a single 25 minutes hypnosis audio session read by a certified hypnotherapist which aims to ‘help reduce anxious thoughts and prepare the mind for deeper, more restorative rest’. This can be combined with background music and sleep booster with binaural beats (only in pro version).

**Non-auditory stimuli**
*Beltone Tinnitus Calmer* and *ReSound Relief* contain some secondary stimuli i.e. colours. The role of those was described as ‘keeping your mind occupied’. For each of the soundscapes there is a possibility of choosing ‘colour mood’ which will be displayed while playing the sound.

*Nature Sounds, Sleep Bug, Sleep Pillow, and Tinnitus Aid* pointed in the app descriptions to using high quality graphics. However, some other apps that did not explicitly specify that feature also featured high quality images (e.g. *White Noise Free*).

**Technical features**
All 18 apps did not require streaming but instead the content was downloaded to the device and worked offline. Seven apps had remote controls allowing to adjust volume (*White Noise Free*) and/or pause/start/close the apps while on the screen lock (*Beltone Tinnitus Calmer, Oticon Tinnitus Sound, Relax Melodies, ReSound Relief, White Noise Free, Sleep Bug, and Sleep Well Hypnosis*).
Five apps had different options for sharing, with White Noise Free featuring the most advanced sharing options of all the apps. These included the possibility of the user sharing their own recordings and mixes and photos. Sharing recordings/mixes is possible via White Noise Market app which connects you to an app community or via email. Headspace allows you to invite up to five ‘buddies’ through an email message, sends the information about the app, a short video, and link to the website. The ‘buddies’ system allows you to access your buddies’ stats and progress and motivate them if they fail to meet the goals. Relax Melodies, Sleep Well Hypnosis, Tinnitus Aid, and Zenways had an option to share the link to the app e.g. via email or messaging apps. myNoise and White Noise Free featured their own app communities where you can upload, download and/or rate different sounds and/or post comments.

Thirteen apps were advert free (Beltone Tinnitus Calmer, Headspace, myNoise, Nature Sounds, Oticon Tinnitus Sound, Rain Rain Sleep Sounds, Relax Noise 3, ReSound Relief, Sleep Bug, Sleep Well Hypnosis, Tinnitus Balance, Tinnitus Therapy Lite, and Zenways), while three apps featured adds on the small stripe at the top or bottom of the screen, not interfering with the apps content (Relax Melodies, Sleep Pillow, and White Noise Free). Soothing Sounds Lite was the only app where the adverts took considerable space on the screen making it difficult to navigate.

Beltone Tinnitus Calmer, Headspace, Relax Melodies, ReSound Relief, and Tinnitus Balance offered progress/usage tracking. Headspace captured the total time spent on meditation, number of sessions completed and average duration. Beltone Tinnitus Calmer and ReSound Relief captured total hours used and separately time spent using sounds and exercises. Tinnitus Balance reported average usage per day, percentage time spent on sounds sorted according to sound type and sounds sorted according to situation down to percentage of time spent listening to individual sounds. Relax Melodies had an option to track ‘mindful minutes’ using the Apple Health app.

Ten apps were available in multiple language options in addition to English (Beltone Tinnitus Calmer, Nature Sounds, Oticon Tinnitus Sound, Rain Rain Sleep Sounds, Relax Melodies, ReSound Relief, Sleep Pillow, Soothing Sounds Lite, Tinnitus Aid, and Tinnitus Balance) and White Noise free was available in English and Spanish.

Fifteen apps featured a timer for controlling the length of the sound or meditation sessions (Zenways). Some of them had an option to fade audio out (Relax Noise 3, Tinnitus Aid, and White Noise Free). The Headspace app did not feature a timer and had a predefined meditation sessions...
length. Soothing Sounds Lite did not have a timer meaning that sounds would play until they were turned off. The timer option was displayed but not accessible in the free version of Sleep Well Hypnosis app. Three apps had a clock (White Noise Free, Sleep Bug and Relax Melodies - iPhone only), Three had alarms (White Noise Free, Soothing Sounds Lite and Relax Melodies – iPhone only), and one had date display (Sleep Bug). Two apps (Rain Rain Sleep Sounds, Relax Melodies) featured bedtime reminders allowing the user to set days and times for going to sleep.

In the description in the app store White Noise Free claimed to feature swipe gesture support for navigating sound collection it is not clear however how that differed from other tested apps. Sleep Bug claimed to use accessibility support, however did not specify in what way. Sleep Bug claimed 'great user support' but again did not clarify what it would feature.

**DISCUSSION**

**Principal findings**

The current study generated the list of 55 apps that people use for management of their tinnitus and explored reasons for app non-use as well as motivators for using apps for tinnitus management. The main reason for apps non-use was lack of awareness of their existence. Quality assessment of the 18 most popular apps, using MARS resulted in a range of mean scores from 1.6 to 4.2 (out of 5) depending on an app. Sound was the main component of the majority of the apps chosen by people with tinnitus.

The data from the Office of National Statistics [17] showed an increasing use of the internet by those aged over 65 despite that this group have been consistently the lowest users of internet over the years. A similar pattern was found for apps' use, with the app users group being slightly younger than the apps non users group. The users' group showed a lower proportion of people aged 65 and over and a higher proportion of people aged 45-54 However there was still a considerable proportion of people over 65 who were app users.

People listed a large number of apps used for tinnitus management. A majority of the 55 apps were mentioned by only one person. There might be several reasons for such variability. Firstly people were looking for apps for a range of different reasons including helping with sleep, masking, sound enrichment, distraction, relaxation, and reducing stress/anxiety, therefore they were choosing apps that were addressing those specific goals or problems. This also explains why the majority of apps used by people were developed for other problems rather than for tinnitus. Secondly, only 19% of respondents reported that they followed a recommendation when choosing an app suggesting that
the majority of respondents found apps through a search in the app stores. A quick search for tinnitus apps in the Google Play Store returned 248 apps available for download. The large number of apps that can potentially be useful for the management of tinnitus, although encouraging, also poses a challenge for people with tinnitus and hearing care professionals equally. The search results for apps in the app store can be overwhelming with several hundred apps available when searching for ‘tinnitus’. Without a clear criteria or guidance on which apps to choose it is not surprising that people tended to choose different apps based on the reviews or personal preference. Given that ease of use was listed as the most important factor when choosing an app it would not be surprising if personal preference played a main role in the choice of apps.

Average MARS quality scores for the 18 most cited apps varied greatly with two apps not meeting the minimum acceptability score of 3. None of the apps received the maximum score of five. The lowest median score was for the aesthetics subscale, which asked questions about layout, graphics quality and visual appeal. The Functionality scale had a highest median score, with questions about performance, ease of use, navigation and gestural design. This is in line with the results of previous studies using MARS for quality assessment of weight management apps [18], prevention of driving after drinking alcohol apps [19], and mindfulness-based apps [20] where functionality scores were also the highest.

In line with the current model of tinnitus management, where sound is the main component of the majority of tinnitus management strategies and programmes, sound was also the main focus of the majority of apps. Current sound therapy options available on the NHS include various devices that play sounds, including sound generators and combination aids. However, those devices can only play a limited number of sounds, therefore not all patients find an option that helps with their tinnitus. As the choice of sound options that can be delivered via many of the apps is large and very often sounds are customisable, it is much more likely that the individual patients’ needs regarding sound therapy will be met via this option, allowing for personalisation of a tinnitus management plan.

About 20% of people with tinnitus experience symptoms that affect their quality of life. They might experience disturbed sleep, hearing and concentration problems, social isolation, anxiety, depression, irritation or stress. It is therefore not surprising that people listed apps addressing those problems through meditation and mindfulness, relaxation exercises, and elements of CBT. However, it was noted during the quality assessment using the MARS scale that some of the content might
not be appropriate for people with tinnitus to access without guidance from a healthcare professional. Specifically Beltone Tinnitus Calmer and ReSound Relief apps have a section giving examples of negative thoughts which without a proper explanation might potentially have a negative impact on the user.

**Strengths and limitations**
This study is the first on to review mobile apps for management of tinnitus. It is the first study to assess quality of apps used for tinnitus management using the MARS scale. Apps were tested on both iPhone iOS and Android platforms. Expert ratings on 30% of the reviewed apps had a high level interrater reliability in the current study.

Given the large number of apps for tinnitus management and the fact that people with tinnitus use both tinnitus-specific apps and apps developed for other problems we have undertaken a bottom up approach, rather than a systematic search in the apps stores. The strength of such approach is that we were able to identify apps not developed specifically for tinnitus that people use and that might potentially be useful for tinnitus management. One of these apps that would not be identified by simple search was Headspace: Guided Meditation & Mindfulness. On the other hand there might be some apps that were missed from our list. Given that this is the first study looking at apps for tinnitus it seemed the best approach to in the first instance look at the apps currently used by people with tinnitus.

**Future research**
Our study showed that people use apps for the management of their tinnitus, however this is done mostly as a self-help option without conjunction with management provided by hearing healthcare professionals. Future research should look at the possibility of incorporating apps into the management of tinnitus by healthcare professionals and creating guidelines for the use of apps as a part of a tinnitus management plan. Further research involving patients and clinicians on the desired content and usability features of apps for tinnitus management should be conducted. There is no evidence for the efficacy of apps for the management of tinnitus and none of the listed apps was assessed for efficacy for tinnitus management in a trial. Future research is needed to determine the efficacy of apps for management of tinnitus.

**Conclusions:**
Further research should consider the place for apps in the tinnitus management (standalone self-management intervention vs part of the management by a hearing professional). As content of the
apps varies in respect to sound options, information and management strategies it seems that the choice of the best management app should be guided by individual patient needs and preferences.

Acknowledgements
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Conflicts of interest
None declared

Abbreviations
BTA: British Tinnitus Association
BRC: Biomedical Research Centre
CBT: Cognitive behaviour therapy
MARS: Mobile Apps Rating Scale
NHS: National Health Service
NIHR: National Institute for Health Research

Multimedia Appendix 1
Checklist for Reporting Results of Internet E-Surveys (CHERRIES)

Multimedia Appendix 2
Coding manual developed for content analysis of the apps

Multimedia Appendix 3
Characteristics of the 55 apps listed by respondents as those they have used for management of their tinnitus

References


