



Benefits and Shortcomings of Direct-to-Consumer Hearing Devices

Vinaya Manchaiah, Aryn Amlani, Christina Bricker, Clayton Whitfield,
Pierre Ratinaud

► To cite this version:

Vinaya Manchaiah, Aryn Amlani, Christina Bricker, Clayton Whitfield, Pierre Ratinaud. Benefits and Shortcomings of Direct-to-Consumer Hearing Devices: Analysis of Large Secondary Data Generated From Amazon Customer Reviews. *Journal of Speech, Language, and Hearing Research*, 2019, 62 (5), pp.1506-1516. 10.1044/2018_JSLHR-H-18-0370 . hal-03657782

HAL Id: hal-03657782

<https://ut3-toulouseinp.hal.science/hal-03657782>

Submitted on 3 May 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0
International License

Research Article

Benefits and Shortcomings of Direct-to-Consumer Hearing Devices: Analysis of Large Secondary Data Generated From Amazon Customer Reviews

Vinaya Manchaiah,^{a,b,c} Aryn M. Amlani,^d Christina M. Bricker,^e
Clayton T. Whitfield,^d and Pierre Ratinaud^f

Purpose: The current study was aimed at understanding the benefits and shortcomings of direct-to-consumer hearing devices (DCHDs) by analyzing the large text corpus of secondary data generated from Amazon customer reviews.

Method: Secondary data were generated manually by gathering user feedback for 62 different DCHDs (cost range: \$9.95–\$635) on the Amazon.com website, which included 11,258 unique Amazon-verified customer reviews. The data were analyzed using both quantitative and qualitative analyses methods.

Results: The cluster analysis of large data corpus resulted in 7 unique clusters, which were labeled as (a) *Issues related to fit and comfort* (15%), (b) *Friends and family recommendations* (11.8%), (c) *Issues related to sound quality* (11.9%), (d) *Listening and conversation* (16.1%), (e) *Positive customer service* (12.1%), (f) *General usage and customer service* (14.7%), and (g) *Cost and affordability* (17.3%). Exploratory analysis also revealed an association between customer ratings and cost in relation to these

clusters (i.e., customer reviews). For example, customer reviews about cheaper DCHDs are related to issues about sound quality, whereas reviews about expensive DCHDs are related to cost and affordability of the device. The qualitative content analysis resulted in 8 main themes, which include (a) intrinsic factors, (b) extrinsic factors, (c) supplemental items, (d) ease of use, (e) interaction with support services, (f) reasons for purchase, (g) experiences, and (h) general information.

Conclusions: The study using the text mining techniques highlights the benefits and shortcomings of DCHDs that are currently available in the U.S. market. Our findings relate well to the published study results of electroacoustic analysis on similar products, which provide clinicians with knowledge related to DCHDs that they can convey to consumers during clinical consultations. The findings may also be of interest to the hearing instrument industry from the perspective of developing products based on user feedback.

It is estimated that, globally, there are 466 million people with disabling hearing loss (World Health Organization, 2018). Untreated hearing loss can have physical, mental, and social consequences for people with hearing loss and for their significant others, including

loneliness, social isolation, loss of productivity, and depression (Manchaiah & Stephens, 2013). Hearing aids are one of the common forms of management options recommended for people with hearing loss (Laplante-Lévesque, Hickson, & Worrall 2010). However, current supply of hearing aids appears to meet less than 10% of the global need (World Health Organization, 2017).

Hearing aids are categorized as medical devices in many countries by regulatory agencies (e.g., U.S. Food and Drug Administration [FDA]). Hence, people with hearing loss need to have a professional consultation to obtain hearing aids. However, people can obtain hearing devices through the direct-to-consumer service delivery model without a professional consultation. These direct-to-consumer hearing devices (DCHDs) include devices such as personal sound amplification systems and over-the-counter (OTC) hearing aids. Personal sound amplification system devices are not intended for people with

^aDepartment of Speech and Hearing Sciences, Lamar University, Beaumont, TX

^bDepartment of Speech and Hearing, School of Allied Health Sciences, Manipal University, Karnataka, India

^cAudiology India, Mysore, Karnataka

^dDepartment of Audiology and Speech Pathology, College of Health Professions, University of Arkansas for Medical Sciences, Little Rock

^eCollege of Nursing, University of South Florida, Tampa

^fLERASS Laboratory, University of Toulouse, France

Correspondence to Vinaya Manchaiah: vinaya.manchaiah@lamar.edu

Editor-in-Chief: Frederick (Erick) Gallun

Editor: Lori J. Leibold

Received September 11, 2018

Revision received November 20, 2018

Accepted December 13, 2018

https://doi.org/10.1044/2018_JSLHR-H-18-0370

Disclosure: The authors have declared that no competing interests existed at the time of publication.

hearing loss (e.g., cannot treat, cure, or mitigate disease nor alter the structure or function of the body) and generally are not marketed for people with hearing loss. OTCs, on the other hand, are FDA-approved hearing aids and are expected to be labeled for listeners with mild-moderate hearing loss but are supplied using a direct-to-consumer model.

Historically, only a small percentage of people with hearing loss seek help and adopt rehabilitation (Amlani & Hosford-Dunn, 2016; Valente & Amlani, 2017). This may be related to various reasons, such as personal factors (e.g., source of motivation, expectation, attitude), demographic factors (e.g., age, gender), and external factors (e.g., cost, counseling), as reviewed by Knudsen, Öberg, Nielsen, Naylor, and Kramer (2010). Moreover, Contrera, Wallhagen, Mamo, Oh, and Lin (2016) present five major obstacles to obtaining effective hearing and rehabilitative care, which include (a) awareness, (b) access, (c) treatment options, (d) cost, and (e) device effectiveness. To overcome the obstacles related to access and cost, many individuals with hearing loss have embraced direct-to-consumer sound-amplifying products (JapanTrak, 2015; Kochkin, 2010). Hence, there is some interest to explore the application of DCHDs for people with hearing loss (Manchaiah, 2018; Manchaiah et al., 2017; Tran & Manchaiah, 2018).

In the last decade, there has been a surge of DCHDs entering the market stemming from two primary factors. First, advancements in technology have yielded a new category of consumer electronics marketed as hearables (i.e., wireless in-ear computational earpiece), mainly for health and well-being purposes, but also include amplification capabilities that make these devices potentially suitable for people with milder degrees of hearing loss. Second, there has been regulatory changes in countries (e.g., Over-the-Counter Hearing Aid Act of 2017 in the United States) to accept the DCHDs as one strategy to increase accessibility and affordability of hearing devices for people with hearing loss (United States Congress, 2017). For these reasons, there is renewed optimism for an increased demand of DCHDs among people with hearing loss (Consumer Electronics Association, 2014).

Despite the increased demand for these products, consumers should be cautioned regarding a given device's performance. That is, the literature indicates great variability in the design, functionality, and electroacoustic characteristics of DCHDs, especially given that electroacoustic characteristics of these devices are determined with lower than the minimum criteria set for hearing aids (Callaway & Punch, 2008; Chan & McPherson, 2015; Cheng & McPherson, 2000; Reed, Betz, Lin, & Mamo, 2017; Smith, Wilber, & Cavitt, 2016). Some clinical studies have shown that a few recent devices perform comparable to hearing aids, resulting in improved hearing, communication function, and social engagement (Humes et al., 2017; McPherson & Wong, 2005; Sacco et al., 2016). Other results suggest that, although there are risks associated with DCHDs, the benefits outweigh the risks, yielding a positive outlook of DCHDs for adults with hearing loss (for reviews, see Manchaiah, 2018;

Manchaiah et al., 2017; Tran & Manchaiah, 2018). It is important to note that there are a limited number of studies in this area, and those that do exist also have small sample sizes. Hence, large-scale studies are needed to better examine the benefits and shortcomings of DCHDs.

Although the focus of research on DCHDs is limited, there is a large amount of data that can be extrapolated from online customer reviews about the performance of these devices. These can be found in various online customer forums in which customer and/or users will post their experiences related to these devices. For example, the online retailer Amazon has a large inventory of DCHDs. After a product is purchased, Amazon urges its users to post their customer rating (i.e., in 1–5 scale) and reviews (i.e., open text) about the item. The approach of studying the consumer-generated information belongs to a new area of study called *infodemiology*. This is an emerging area of research at the crossroads of consumer health informatics (i.e., field devoted to informatics from multiple consumer or patient views) and public health informatics (Eysenbach, 2000, 2002). The aim of this research is to examine patient and/or customer information from points of view such as health literacy, consumer knowledge, and education, with the ultimate goal to empower patients and/or customers by giving them knowledge they need to make their own decisions (Eysenbach, 2000, 2002). The information gained by examining the large data from consumers can aid in the understanding of consumer knowledge, attitudes, behaviors, and information consumption from the public health viewpoint (Eysenbach, 2009, 2011). The infodemiology methodologies have been used widely in various health areas (for a review, see Zeraatkar & Ahmadi, 2018). It has been suggested that this approach provides unmatched opportunities for the management of health data and information generated by the users (Zeraatkar & Ahmadi, 2018). Moreover, a series of high-impact journals (e.g., *Journal of Medical Internet Research* series) have been dedicated to presenting research based on these methodologies, which highlights their validity in the field of health care. Hence, such an approach to understanding the customer views on DCHDs can be useful for various stakeholders, including hearing health care professionals, hearing instrument consumers, hearing device manufacturers, and the government agencies who make decisions concerning DCHDs.

The current study was aimed at understanding the benefits and shortcomings of DCHDs as reported by consumers through analyzing the large text corpus of secondary data generated from Amazon customer reviews.

Method

Study Design and Ethical Considerations

The study involved a cross-sectional design based on an analysis of secondary data generated from Amazon customer reviews. The study did not require ethical approval as (a) the data were generated from a publicly available

source and (b) data extraction did not identify any individual users and maintained anonymity of the responses, which ensured minimal or no potential risk to individual users (Ainscough, Smith, Greenwell, & Hoare 2018; Dawson, 2014; Eysenbach & Till, 2001).

Data Extraction

A detailed search was conducted on the Amazon U.S. website (<http://www.amazon.com>) to find all possible DCHDs during September 2017 and December 2017. Search words included *direct to consumer hearing device*, *personal sound amplification product*, *personal sound amplification device*, *direct-mail hearing aid*, *over the counter (OTC) hearing aid*, *personal amplifiers*, *sound amplifiers*, *hearing amplifier*, *hearing enhancer*, *basic hearing aid*, *self-fitting hearing aid*, *affordable hearing aid*, and *hear-able(s)*. A comprehensive list of devices was created by only identifying the DCHDs and excluding the hearing aids that are regulated under the FDA. This resulted in identification of 70 devices. Criteria of having at least 10 customer reviews were set to ensure that each device included varied reviews. Hence, eight devices were removed from this list, resulting in a total number of 62 DCHDs for data extraction.

An automated extraction of data was attempted using custom-written extraction software. However, two problems were noticed. First, the automated software code was unable to extract online review data from over 20 devices due to issues with the Amazon firewall. Second, the automated software code could not differentiate verified versus unverified reviews. Hence, a manual extraction of the user feedback and other device-related details was conducted, yielding a total of 12,087 unique user reviews across 62 DCHDs. Two authors (i.e., C. M. B. and C. T. W.) provided an additional manual screening of the data corpus to ensure that the data included only Amazon-verified reviews. This second parsing reduced the data corpus down to 11,258 unique, verified user reviews.

The data corpus was separated into two separate data sets. The first data set consisted of an Excel file containing information about the 62 DCHDs, which included information such as device-specific URL, number of reviews, number of verified reviews, average rating (rating on a 5-point scale), and cost of the device. This data set was used for exploratory descriptive analysis. The second data set consisted of a text file containing information about the 11,258 unique user reviews, and the associated meta data, such as device identification number, individual user rating (rating on a 5-point scale), year the review was posted, and cost of the device. This text-based data set was used for the automated text analysis and for qualitative content analysis. The cost of the device was captured in both data sets. In the first data set, the relationship between the average rating for the device and the cost of the device was examined. However, in the second data set, the relationship between the individual customer review (i.e., text) examined through an automated cluster analysis (see Data

Analysis section for details) and its association with the cost of the device was examined.

Data Analysis

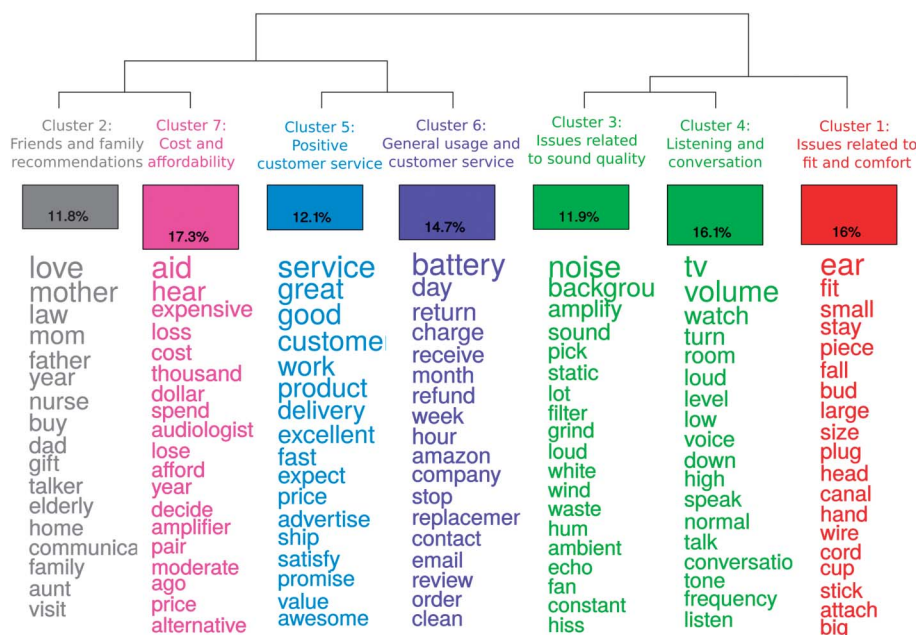
The data were analyzed using both quantitative (i.e., Spearman correlation, cluster analysis, chi-square analysis) and qualitative (i.e., content analysis) methods. The quantitative analyses were conducted using the open source IRaMuTeQ software (<http://www.iramuteq.org/>).

First, the data set with device-related information was examined using descriptive statistics. In addition, we used Spearman correlation to examine the relationship between the cost of the device and the average customer rating.

Second, a cluster analysis was conducted on the text corpus to examine the broader themes reported by reviewers for all 11,258 reviews. Cluster analysis was conducted with the Reinert method used for the textual data analysis (Ratinaud & Marchand, 2012; Reinert, 1983). The Reinert method uses a divisive hierarchical clustering known to improve the text data analysis (Sbalchiero & Tuzzi, 2017). The cluster analysis groups the text segments based on co-occurrence of lemmas (i.e., group of words in a single form). The cluster analysis aims to produce each cluster, which is as homogeneous (i.e., having text segments with the common pattern of lemmas) as possible within the cluster and as heterogeneous as possible between the clusters. The software produces results in a dendrogram that characterizes the clustering. For each cluster, the program computes profiles of lemmas, which are overrepresented, that is, significantly in a higher proportion within the cluster when compared with the rest of the text corpus based on a chi-square analysis (see Figure 1). The number of clusters in the software was set to a maximum of 25. However, the clustering algorithm determines the number of clusters. The same text corpus was subjected to a time series analysis (i.e., how cluster patterns change over time) to see which cluster was significantly more likely to be appearing in each year (see Figure 2). A detailed description of this cluster analysis method has been presented in a previous manuscript (Manchaiah, Ratinaud, & Andersson, 2018). In addition, chi-square analysis was performed to examine the relationship between clusters and factors, such as the Amazon customer rating and the cost of the device (see Figures 3 and 4). Descriptions of Figures 1–4 are provided in Results section.

It is noteworthy that text mining software programs vary in features and functionalities. These features can be grouped into three main aspects, which include (a) extraction of themes within the data corpus (i.e., cluster analysis), (b) identification of sentiments (i.e., positive, neutral, or negative) associated with the texts, and (c) examination of the relationship between metadata and the themes or sentiments. IRaMuTeQ software can help extract themes within the data corpus and examine the relationship between the metadata and the themes (presented in Results section) but does not perform sentiment analysis. The software programs are found to be good in identification of patterns (i.e., themes) within the text corpus

Figure 1. Dendrogram (i.e., classification of clusters), size of clusters as percentage of the text segments, and overrepresented words in each cluster in the Amazon customer reviews of direct-to-consumer hearing devices. (The words are ordered by chi-square value with words at the bottom having lower value.)



(Ratinaud & Marchand, 2012; Reinert, 1983). However, there is some criticism about the reliability of sentiment analysis (Ding & Pan, 2017). For this reason, we did not consider other software programs for performing the automated sentiment analysis for the textual data.

Finally, a qualitative analysis was performed to examine specific themes in the user reviews. Verbatim Amazon reviews were analyzed using content analysis and constant comparison methods (Graneheim & Lundman, 2004; Rubin & Rubin, 2012; Streubert & Carpenter, 2011) with a representative segment of the data ($n = 1,125$ reviews; 10% of the data). Each 10th review was selected and entered into MAXQDA 2018 software (VERBI Software, 2017), which numbers each line of data (Streubert & Carpenter, 2011). This kept the data organized and facilitated retrieval of data for analysis. The software permits searching and sorting of data by multiple codes. This aids with grouping data, linking concepts and themes, and locating evidence (Rubin & Rubin, 2012). After entering 1,125 reviews into the MAXQDA software, we performed an initial content analysis. Content analysis is a line-by-line review of the data and identification of key concepts (Rubin & Rubin, 2012). We analyzed the manually coded reviews by line number, carefully reading and rereading the reviews to interpret the meaning of and assigning labels (praise about accessibility, poor customer service, purchased as a gift, etc.) to passages of text. Next, initial coded words and definitions were developed. A code book was developed from the examination of the initial reviews and was agreed upon by the two researchers (i.e., C. M. B. and C. T. W.). Table 1 presents examples of code book

entries. These codes and their precise definitions then served as a guide for coding all reviews. Data analysis continued until theoretical saturation was achieved, which was determined by the repetition of theoretical material with failure to yield new relevant data with continued sampling (Streubert & Carpenter, 2011). Following content analysis and coding of each review, we then used the technique of constant comparison, an iterative process of comparing and contrasting each datum with all other data to gain conceptual understanding. MAXQDA 2018 software was used to search for similarly coded data and to segregate data by topic. The data on each topic were carefully compared to identify meanings, similarities, differences, and relationships. The data were then aggregated and clustered into increasingly abstract, interrelated units of meaning or categories to develop themes and subthemes (see Table 3). Qualitative researchers (i.e., C. M. B. and C. T. W.) were not exposed to results of automated text analysis until the qualitative data analysis was complete to ensure there was no bias in the analysis.

Results

Descriptive Analysis

Exploratory analysis suggested that there were 12,087 ($M = 191.86$, $SD = 200.34$, range: 13–759) unique customer reviews for the 62 DCHDs in the Amazon.com website. Of these, 11,258 ($M = 178.7$, $SD = 190.66$, range: 12–724) were Amazon-verified customer reviews, which were included in further analysis. The average customer

Figure 2. Chronological bar based on chi-square analysis showing the proportion of each cluster for each year in the Amazon customer review text corpus (the width of the bar is proportional to the number of text segments each year, and the height of the bar represents the size of the clusters). The clusters that are significantly overrepresented in each year are highlighted.

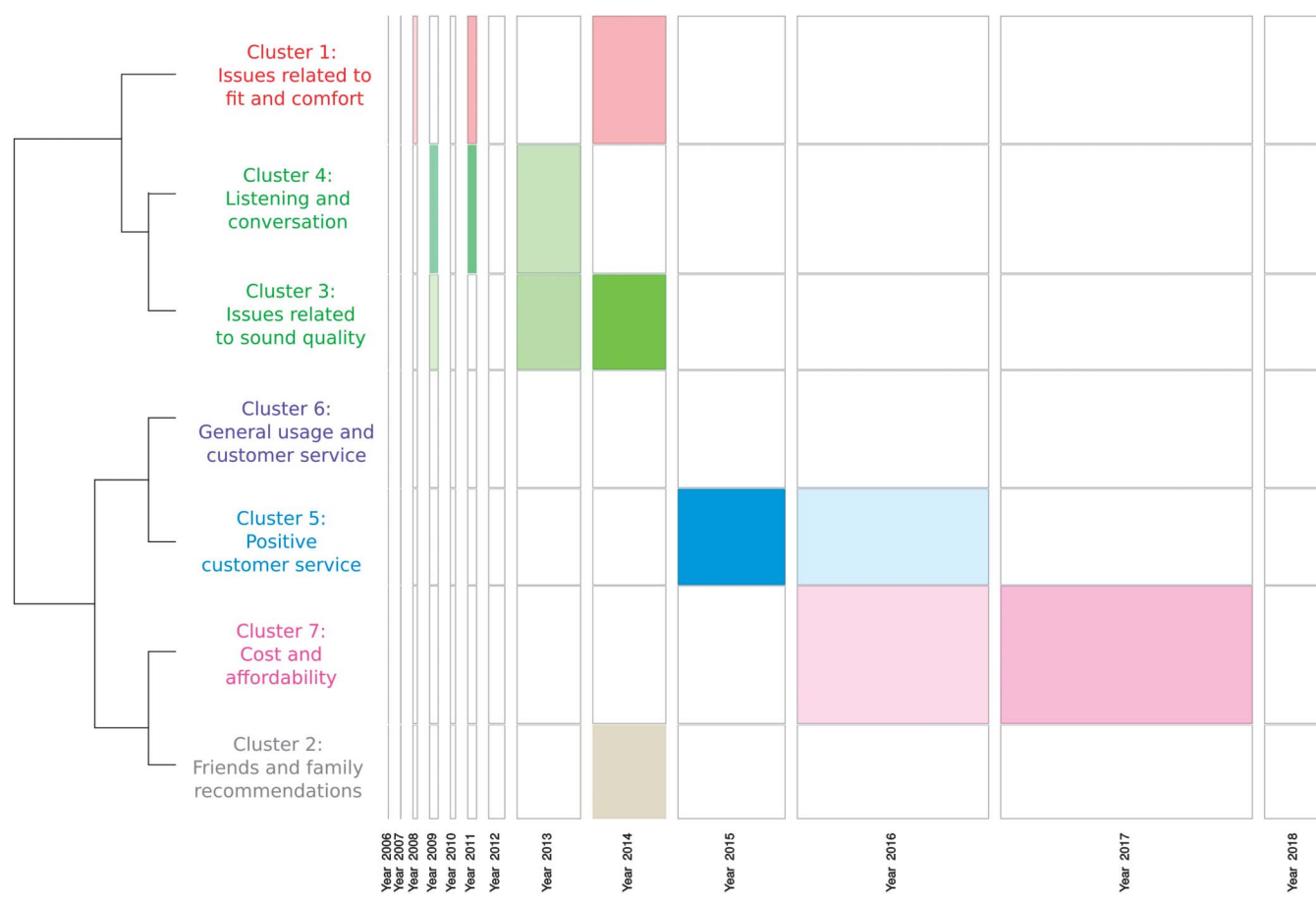


Figure 3. Association between clusters and Amazon customer ratings of direct-to-consumer hearing devices.

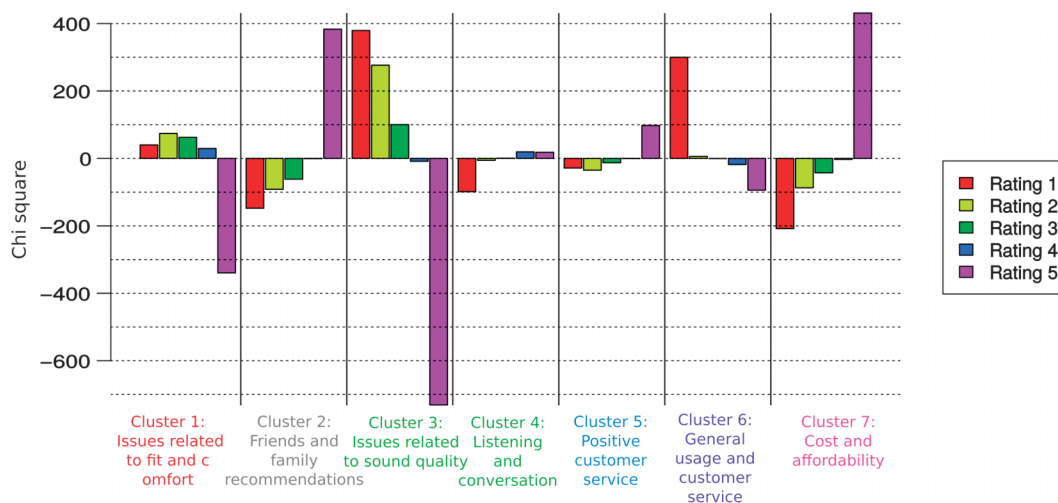


Figure 4. Association between clusters and the cost of direct-to-consumer hearing devices.



rating in a 1–5 scale was 3.43 ($SD = 0.54$, range: 2.4–4.5). Also, the average cost of the device was \$98.69 ($SD = 126.3$, range: \$9.95–\$635). Spearman correlation showed a moderate positive correlation ($r = .605$, $p < .01$) between the customer rating and the cost of the device, suggesting some association between device cost and the customer rating. Close examination of the reviews indicates that many friends and family members who bought the device for their significant others provide a proxy report about the device when providing the Amazon customer reviews, although these reviews provide very useful information about the experience of the user.

Cluster Analysis

Figure 1 provides the cluster analysis results of the Amazon customer reviews text corpus. In Figure 1, the font size of words within each cluster is proportional to the chi-square value in that cluster (i.e., larger font size indicating larger chi-square value), but we cannot compare the size between clusters. The cluster analysis yielded seven

clusters. Table 2 provides examples of text segments that typically represent each of the seven clusters. The clusters were named by examining the most frequently occurring words within each cluster and the typically occurring text segments. Cluster 1 consisted of 15% of the text, which was focused on instrument usage and was named as *Issues related to fit and comfort*; Cluster 2 was the smallest cluster, which consisted of 11.8% of the texts and was focused on *Friends and family recommendations*; Cluster 3 included 11.9% of the texts and was focused on *Issues related to sound quality*; Cluster 4 consisted of 16.1% of the texts and was focused on *Listening and conversation*; Cluster 5 was focused on *Positive customer service* and contained 12.1% of the texts; Cluster 6 included 14.7% of texts and was related to *General usage and customer service*; and Cluster 7 was the largest cluster, which consisted of 17.3% of texts and was related to *Cost and affordability*.

Analysis of Trends Over Time

Figure 2 presents a chronological bar with chi-square for Amazon customer reviews. The figures only highlight

Table 1. Example of the codebook.

Code	Definition
Praise (general)	Positive comments about the device to exclude sound quality, sound reduction, accessories, charge time, comfort, customer service, specific features, adjustment period, aesthetics, accessibility, or price
Poor sound quality	Negative comments about wanted (or desired) sounds
Comfortable	Positive comments about the device feels when worn
Praise about accessibility	Positive comments regarding the device's handling for tasks such as battery changing, manually adjusting the volume, or pressing buttons
Complaint about extension	Negative comments about additional components of the device excluding hardware, software, and accessories
Praise about user friendliness	Positive comments about the simplicity of function and overall user friendliness of the device
Ambivalent (general)	Comments suggesting mixed feelings about the device to exclude sound quality, sound reduction, accessories, charge time, comfort, customer service, specific features, adjustment period, aesthetics, accessibility, or price

Table 2. Example of a text segment for each cluster in the Amazon customer reviews of the direct-to-consumer hearing devices.

Cluster	Example of a text segment
Cluster 1: Issues related to fit and comfort	i have tried all the earplug sizes and they don't stay put in my ear as my ear canals are small i have to hold it in place but i think if you have normal ear canals it prob works fine
Cluster 2: Friends and family recommendations	bought for my hearing impaired 95 year old mother in law in a nursing home this opened up her world when we talk to her works great i like that it takes regular batteries the headphones could adjust a little better for her smaller size would recommend to others
Cluster 3: Issues related to sound quality	So background noise hums and anything in the area gets louder the lack of any filters or tone modification makes everything sound loud and like an old staticky transistor radio they amplified zero bottom end frequency which made everything sound terribly unnatural
Cluster 4: Listening and conversation	he really loves it he does not like to be without it we can actually have a normal conversation he also watches his tv with the volume turned down to a normal level i give your pocket talker a solid 5 from our neighbor
Cluster 5: Positive customer service	this unit gets great reviews and now i understand why it works as described delivery was quicker than promised customer service is as good as other reviewers said it was
Cluster 6: General usage and customer service	works great for my mother the cost was excellent well after i said it worked great i put in new battery now it doesn't work tried another battery still doesn't work of course now its 2 days after return time it lasted a month
Cluster 7: Cost and affordability	i wanted to get something like this because i have moderate hearing loss and could not justify spending thousands of dollars on actual hearing aids when my hearing was tested my audiologist suggested hearing amplifiers instead of hearing aids

the cluster that shows a chi-square value of 3.84 or more; furthermore, a statistical significance (i.e., p value below .05) is demonstrated. This figure provides information on how the clusters related to Amazon customer reviews change over time and helps us understand trends in customer feedback. For example, in Figure 2, it is evident that Cluster 5 (i.e., Positive customer service) is significantly overrepresented in the year 2015 and Cluster 7 (i.e., Cost and affordability) is significantly overrepresented in the year 2017, whereas both Clusters 5 and 7 are significantly overrepresented in the year 2016. Overall, the time series analysis of clusters indicated changes in the pattern of Amazon customer reviews for DCHDs.

Association Between Clusters and Device-Related Variables

A chi-square analysis was performed to examine the association between clusters and also Amazon customer ratings and costs of the devices, which are presented in Figures 3 and 4, respectively. These figures only highlight the cluster that shows a chi-square value of 3.84 or more; furthermore, a statistical significance (i.e., $p < .05$) is shown. The graphs are interpreted by considering the overrepresentation or underrepresentation of variables (e.g., customer rating, cost of the device) in each of the clusters. The bars going up indicate a statistical overrepresentation (a higher proportion), and the bars going down indicate a statistical underrepresentation (a lower proportion) of customer rating or cost of the device in relation to each cluster. The length of the bars indicates the strength of overrepresentation or underrepresentation.

Figure 3 shows that a customer rating of 5 (indicating *highest satisfaction*) is significantly overrepresented in Cluster 2 (i.e., Friends and family recommendations) and Cluster 7 (i.e., Cost and affordability), whereas it is

significantly underrepresented in Cluster 1 (i.e., Issues related to fit and comfort) and Cluster 3 (i.e., Issues related to sound quality). Also, a customer rating of 1 (indicating *lowest satisfaction*) is significantly overrepresented in Cluster 3 (i.e., Issues related to sound quality) and Cluster 6 (i.e., General usage and customer service), whereas it is significantly underrepresented in Cluster 2 (i.e., Friends and family recommendations) and Cluster 7 (i.e., Cost and affordability). These results indicate that customer reviews related to issues about sound quality, fit and comfort, and general usage and customer service can be related to a lower satisfaction rating. However, customer reviews about recommendations made by friends and family, as well as device cost and affordability, are related to a higher satisfaction rating.

Figure 4 shows that DCHDs with the cost range of \$0–\$50 (indicating cheaper devices) are significantly overrepresented in Cluster 3 (i.e., Issues related to sound quality), whereas it is significantly underrepresented in Cluster 7 (i.e., Cost and affordability). However, DCHDs with the cost range of \$201–\$500 (indicating expensive devices) are significantly overrepresented in Cluster 7 (i.e., Cost and affordability) and Cluster 6 (i.e., General usage and customer service), but they are significantly underrepresented in Cluster 1 (i.e., Issues related to fit and comfort) and Cluster 2 (i.e., Friends and family recommendations). These results indicate that customer reviews about cheaper DCHDs are related to issues about sound quality, whereas reviews about expensive DCHDs are related to cost and affordability of the device.

Qualitative Content Analysis

The qualitative content analysis identified eight main themes and 40 subthemes (see Table 3). These included (a) intrinsic factors, (b) extrinsic factors, (c) supplemental items, (d) ease of use, (e) interaction with support services,

(f) reasons for purchase, (g) experiences, and (h) general information. The main subthemes that were occurring more frequently included great sound quality, poor sound quality, purchased as gift, satisfactory experience, dissatisfactory experience, and general information. The themes and subthemes identified customer reports about the DCHDs.

Discussion

The current study explored the benefits and shortcoming of DCHDs by analyzing the large text corpus generated from Amazon customer reviews. The data were analyzed using both qualitative and quantitative analyses methods. The study identified important aspects related to consumer review highlighting issues related to fit and comfort, sound quality, cost and affordability, customer service, and recommendations for the device. Understanding the patient and/or customer reviews provides insight into their knowledge, attitudes, and experiences (Eysenbach, 2000, 2002). This understanding can help hearing health care professionals to develop appropriate strategies to empower individuals who are interested in using DCHDs to make informed decisions.

In this study, exploratory analysis indicated a positive association between the cost of the device and the customer rating of the device. Our finding is confirmed by previous studies that assessed the electroacoustic characteristics of the DCHDs, demonstrating that devices with higher cost had better acoustic quality than lower priced devices (Reed et al., 2017; Smith et al., 2016). The reader should be cautioned, however, that many of the online reviews might have been written by friends and family members of people with hearing difficulties. Although these proxy reports have their own advantage (Magaziner, Bassett, Hebel, & Gruber-Baldini, 1996; McPhail, Beller, & Haines, 2008), the accuracy of the reviews in terms of sound quality may be questionable as the reviewers did not have firsthand experiences using the devices.

In addition, the automated text pattern analysis used in this study identified seven main themes from online reviews. These were related to issues related to fit and comfort, friends and family recommendations, sound quality, listening and conversation, positive customer service, general usage and customer service, and cost and affordability. As expected, the quantitative analysis did not yield a single dominating theme across the reviews, a similar theme found in the MarkeTrak reports (Abrams & Kihm, 2015; Kochkin, 2009). The lack of a primary trend suggests that customer perceptions about DCHDs—and amplification, in general—vary considerably regarding issues ranging from quality of the device to its usage and to the service delivery model.

Careful examination of the qualitative content analysis, on the other hand, suggested that reviewers' primary comments centered around three main themes: (a) sound quality (both positive and negative), (b) praise about the

instrument and its cost, and (c) complaints about the instrument. In addition, the qualitative analysis further identified new elements that were not evident in the quantitative analysis. For example, the Cluster 2 (i.e., Friends and family recommendations) in the quantitative analysis relates to subtheme “purchased as a gift” in the qualitative analysis, although the qualitative analysis provided more direct understanding of the customer reviews. Together, the use of a combined qualitative and quantitative approach supports generalizations by counts of events, ultimately improving the validity and reliability of the data set and the generalized findings (Seale & Silverman, 1997).

It is noteworthy that the automated text pattern analysis was used as the primary method of analysis of consumer reviews about DCHDs. Automated and computer-assisted methods of extracting, organizing, conceptualizing, and understanding large quantities of unstructured text provide an effective way to gain insights into consumer reviews. The automated text pattern analysis often uses cluster analysis techniques, which identify important themes (i.e., meaningful information) within the data. Such approaches are much needed in the health care sector as health care devices (e.g., hearing devices) undergo significant changes in terms of features and functionalities and sometimes do not even exist before the evidence base is produced (Institute of Medicine, 2008). However, people may purchase and use such devices and provide feedback about the usage in consumer forums. Hence, examining the customer reports may serve as initial evidence for health care products and devices. We believe that the use of such techniques will become fundamental in generating evidence base in health care and contribute to sound health care decision making in the future.

Practice Implications

As discussed earlier, DCHDs are mandated for people with normal hearing sensitivity who wish to improve their listening acuity for a given activity (e.g., bird watching, hunting). Despite the mandate, individuals with hearing difficulties may be purchasing DCHDs in lieu of traditional hearing aids (JapanTrak, 2015; Kochkin, 2010; Manchaiah et al., 2017) and without the consultation of a hearing health care professional to diagnose the status of a listener's hearing sensitivity. From a service delivery standpoint—and because of the limited research in this developing area—it is challenging for hearing health care professionals to determine which technology best meets the listener's needs and at a cost that justifies the performance level accompanied with that product. In addition, the current study sheds light on various aspects of consumer perception toward alternative amplification technology based on the Amazon reviews that were analyzed in this study. For example, perceptions about the sound quality of the device, cost of the device, and customer service were reported as representing primary considerations in the adoption and acceptance of this alternative technology.

Table 3. Themes and subthemes identified in the qualitative content analysis of Amazon customer reviews of the direct-to-consumer hearing devices.

Themes	Subthemes	Number of meaning units	Example of meaning unit
Intrinsic factors	Great sound quality	221	"The sound is very clear with no distortion."
	Poor sound quality	203	"Did not do much to amplify the sound."
	Praise about features	41	"The choice of programs gives the user options that cover most situations."
	Complaint about features	23	"Would rather have one that has bluetooth capabilities."
	Short adjustment period	11	"I also found it very easy to get used to."
	Long adjustment period	19	"Fitting it takes some patience and forbearance."
Extrinsic factors	Comfortable	52	"I find I don't even notice I'm wearing."
	Uncomfortable	83	"He does have some trouble to keep it in his ear."
	Great aesthetic	23	"Is discreet in appearance."
	Poor aesthetic	26	"They are much larger than I believed them to be."
	Praise about hardware	53	"The rechargeable battery is very useful and convenient."
	Complaint about hardware	41	"Developed a short circuit, got hot and buzzed."
	Praise about lifespan	9	"I have had this product for over two years."
	Complaint about lifespan	32	"Dead right out of the box."
	Praise about build quality	2	"It is well made."
	Complaint about build quality	13	"Housing of the device feels cheap."
	Good overall package	18	"It came in a little hard box/caring case that made it easy for me to store."
Supplemental items	Poor overall packaging	14	"The spray provided kills it."
	Praise about extension	3	"The LifeEar earpiece works well and is not a poor design by any means."
	Complaint about extension	21	"Ear pieces too difficult to use."
Ease of use	Praise about accessibility	17	"It was extremely easy to adjust sound range."
	Complaint about accessibility	15	"I had a hard time adjusting the sound because the switch is so small."
	Praise about user friendliness	25	"Simple to operate."
	Complaint about user friendliness	8	"It was a pain to set up."
Interaction with support services	Great customer service	27	"The customer care is terrific."
	Poor customer service	15	"They promised to send me another unit but they haven't. It has been a month and I am still waiting."
	Praise about third party services	12	"Amazon replaced it within two days."
	Complaint about third party services	2	"Can't return the darn thing."
	Praise about advertising	20	"Product worked as advertised."
	False advertising	10	"Advertising is somewhat misleading."
	Customer support questions	9	"Where can I purchase more ear cups?"
	Praise about price	115	"Good for the price!"
	Complaint about price	10	"For the price this is certainly a ripoff."
	Purchased as a gift	106	"This was for my mother-in-law, who uses these amps all the time."
Reason for purchase	Used as a backup	15	"I will only use this as a backup for now."
	Purchased as an introductory hearing aid	2	"When we find these don't 'work' any longer, and if she continues to wear it and need it, then we might try an audiologist for a custom fit."
	Satisfactory experience/praise (general)	442	"I am very happy with this hearing device."
Experiences	Dissatisfactory experience/complaint (general)	181	"This product is junk it does not work."
	Mixed experience/ambivalent (general)	27	"Just ok."
General information	General information	154	"Haven't tried in my car yet."

For manufacturers, findings from the current study are also of importance as reviewer comments provide important feedback with respect to the product's electroacoustic properties, functional features related to fit and comfort, and service delivery aspects (e.g., customer service) that promote satisfaction and loyalty. Finally, for government agencies, our findings encourage development guidelines that warrant regulations of product classification and performance.

Study Limitations and Future Directions

The current study is unique in that we examined a large data set from Amazon regarding consumer perceptions about DCHDs using the text pattern analyses. In addition, the qualitative analysis was performed on 10% of the data. However, qualitative analysis of larger data samples may not have yielded any additional information as we checked for data saturation during the analysis. Despite our efforts, there are limitations to our findings. First, we did not separate the customer reviews between the DCHD user and the user's proxy (i.e., friends, family members). Examination of customer reviews from friends and family members during qualitative analysis revealed that they were indeed important. However, separating the reviews from the individuals who were, in fact, using the devices from the secondary reports from others (i.e., friends and family) may have revealed some commonalities and differences in the views of these two groups. Second, the automated text pattern analysis identified important themes (i.e., clusters). Although common themes were identified, such as "Issues related to fit and comfort" and "Issues related to sound quality," the themes did not distinguish whether the views expressed were positive, neutral, or negative. The qualitative analysis provided more in-depth analysis, in this regard, although it was performed on a smaller data set. Hence, future studies can include additional text mining techniques, such as sentiment analysis, to examine the data in more depth. Third, the customer reviews about DCHDs were only obtained from Amazon. However, reviews from other forums (e.g., DCHD websites, consumer forums such as Hearingtracker.com) may have information that were not identified in this study.

Conclusions

The study examined Amazon customer reviews of DCHDs. The automated cluster analysis of the large text corpus (i.e., text mining) with customer reviews resulted in seven unique clusters, which were named as (a) *Issues related to fit and comfort*, (b) *Friends and family recommendations*, (c) *Issues related to sound quality*, (d) *Listening and conversation*, (e) *Positive customer service*, (f) *General usage and customer service*, and (g) *Cost and affordability*. The customer reviews related to issues about sound quality, fit and comfort, and general usage and customer service can be related to lower satisfaction ratings. However, customer reviews about recommendations made by friends

and family as well as device cost and affordability are related to higher satisfaction ratings. Also, customer reviews about cheaper DCHDs are related to issues about sound quality, whereas reviews about expensive DCHDs are related to cost and affordability of the device. The qualitative content analysis resulted in eight main themes, which include (a) intrinsic factors, (b) extrinsic factors, (c) supplemental items, (d) ease of use, (e) interaction with support services, (f) reasons for purchase, (g) experiences, and (h) general information. This analysis demonstrates positive associations between qualitative and quantitative analysis of the data. Overall, the study results highlight the benefits and shortcomings of DCHDs, which are currently in the U.S. market. These findings can help clinicians to better address issues related to DCHDs and more appropriately advise consumers during clinical consultations. In addition, the findings may also be of interest to the hearing instrument industry from the perspective of developing products, which are developed based on users' feedback.

References

- Abrams, H. B., & Kihm, J. (2015). An introduction to MarkeTrak IX: A new baseline for the hearing aid market. *The Hearing Review*, 22(6), 16–21.
- Ainscough, E., Smith, S. N., Greenwell, K., & Hoare, D. J. (2018). Findings and ethical considerations from a thematic analysis of threads within tinnitus online support groups. *American Journal of Audiology*, 27(S3), 503–512. https://doi.org/10.1044/2018_AJA-IMIA3-18-0013
- Amlani, A. M., & Hosford-Dunn, H. (2016). How do we increase hearing aid adoption rates. *The Hearing Review*, 23(10), 10–11.
- Callaway, S. L., & Punch, J. L. (2008). An electroacoustic analysis of over-the-counter hearing aids. *American Journal of Audiology*, 17(1), 14–24.
- Chan, Z. Y. T., & McPherson, B. (2015). Over-the-counter hearing aids: A lost decade for change. *BioMed Research International*, 2015, 1–15. <https://doi.org/10.1155/2015/827463>
- Cheng, C. M., & McPherson, B. (2000). Over-the-counter hearing aids: Electroacoustic characteristics and possible target client groups. *Audiology*, 39(2), 110–116.
- Consumer Electronics Association. (2014). *Personal sound amplification products: A study of consumers attitudes and behavior*. Retrieved from <https://www.cta.tech/cta/media/policyImages/policyPDFs/Report-Personal-Sound-Amplification-Products-A-Study-of-Consumer-Att.pdf>
- Contrera, K. J., Wallhagen, M. I., Mamo, S. K., Oh, E. S., & Lin, F. R. (2016). Hearing loss health care for older adults. *Journal of the American Board of Family Medicine*, 29(3), 394–403.
- Dawson, P. (2014). Our anonymous online research participants are not always anonymous: Is this a problem. *British Journal of Educational Technology*, 45, 428–437.
- Ding, T., & Pan, S. (2017). How reliable is sentiment analysis? A multi-domain empirical investigation, In V. Monfort, K. H. Krempels, T. Majchrzak, & P. Traverso (Eds.), *Web information systems and technologies. WEBIST 2016. Lecture notes in business information processing* (Vol. 292, pp. 37–57). Cham, Switzerland: Springer.
- Eysenbach, G. (2000). Consumer health informatics. *BMJ*, 320(7251), 1713–1716.

- Eysenbach, G. (2002). Infodemiology: The epidemiology of (mis) information. *American Journal of Medicine*, 113(9), 763–765.
- Eysenbach, G. (2009). Infodemiology and infoveillance: Framework for an emerging set of public health informatics methods to analyze search, communication and publication behavior on the internet. *Journal of Medical Internet Research*, 11(1), e11. <https://doi.org/10.2196/jmir.1157>
- Eysenbach, G. (2011). Infodemiology and infoveillance tracking online health information and cyberbehavior for public health. *American Journal of Preventative Medicine*, 40(5S2), S154–S158.
- Eysenbach, G., & Till, J. E. (2001). Ethical issues in qualitative research on Internet communities. *British Medical Journal*, 323, 1103.
- Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today*, 24(2), 105–112.
- Humes, L. E., Rogers, S. E., Quigley, T. M., Main, A. K., Kinney, D. L., & Herring, C. (2017). The effects of service-delivery model and purchase price on hearing-aid outcomes in older adults: A randomized double-blind placebo-controlled clinical trial. *American Journal of Audiology*, 26(1), 53–79. https://doi.org/10.1044/2017_AJA-16-0111
- Institute of Medicine. (2008). *Evidence-based medicine and the changing nature of health care: 2007 IOM annual meeting summary*. Washington, DC: The National Academies Press <https://doi.org/10.17226/12041>
- JapanTrak. (2015). Retrieved from https://www.ehima.com/wp-content/uploads/2016/02/JAPAN_Trak_2015-1.pdf
- Knudsen, L. V., Öberg, M., Nielsen, C., Naylor, G., & Kramer, S. E. (2010). Factors influencing help seeking, hearing aid uptake, hearing aid use and satisfaction with hearing aids: A literature review. *Trends in Amplification*, 14(3), 127–154.
- Kochkin, S. (2009). MarkeTrak VIII: 25-year trends in the hearing health market. *The Hearing Review*, 16(11), 12–31.
- Kochkin, S. (2010). MarkeTrak VIII: Utilization of PSAPs and direct-mail hearing aids by people with hearing impairment. *The Hearing Review*, 17(6), 12–16.
- Laplanche-Lévesque, A., Hickson, L., & Worrall, L. (2010). Rehabilitation of older adults with hearing impairment: A critical review. *Journal of Aging and Health*, 22(2), 143–153. <https://doi.org/10.1177/0898264309352731>
- Magaziner, J., Bassett, S. S., Hebel, J. R., & Gruber-Baldini, A. (1996). Use of proxies to measure health and functional status in epidemiologic studies of community-dwelling women aged 65 years and older. *American Journal of Epidemiology*, 143(3), 283–292.
- Manchaiah, V. (2018). Direct-to-consumer hearing devices for people with hearing loss: Definitions, summary of literature, and analysis of threats and opportunities. *Perspectives of the ASHA Special Interest Groups*, 3(SIG7), 5–11. <https://doi.org/10.1044/persp3.SIG7.5>
- Manchaiah, V., Ratinaud, P., & Andersson, G. (2018). Representation of tinnitus in the US newspaper media and in Facebook pages: Cross-sectional analysis of secondary data. *Interactive Journal of Medical Research*, 7(1), e9. <https://doi.org/10.2196/ijmr.9065>
- Manchaiah, V., & Stephens, D. (2013). Perspectives in defining ‘hearing loss’ and its consequences. *Hearing, Balance and Communication*, 11(1), 6–16. <https://doi.org/10.3109/21695717.2012.756624>
- Manchaiah, V., Taylor, B., Dockens, A. L., Tran, N. R., Lane, K., Castle, M., & Grover, V. (2017). Applications of direct-to-consumer hearing devices for adults with hearing loss: A review. *Clinical Interventions in Aging*, 12, 859–871. <https://doi.org/10.2147/CIA.S135390>
- McPhail, S., Beller, E., & Haines, T. (2008). Two perspectives of proxy reporting of health-related quality of life using the Euroqol-5D, an investigation of agreement. *Medical Care*, 46(11), 1140–1148. <https://doi.org/10.1097/MLR.0b013e31817d69a6>
- McPherson, B., & Wong, E. T. (2005). Effectiveness of an affordable hearing aid with elderly persons. *Disability and Rehabilitation*, 27(11), 601–609.
- Ratinaud, P., & Marchand, P. (2012). Recherche improbable d’une homogène diversité: Le débat sur l’identité nationale [Improbable search of a homogeneous diversity: The debate on national identity]. *Languages*, 187(3), 93–107. <https://doi.org/10.3917/lang.187.0093>
- Reed, N. S., Betz, J., Lin, F. R., & Mamo, S. K. (2017). Pilot electroacoustic analyses of a sample of direct-to-consumer amplification products. *Otology & Neurotology*, 38(6), 804–808. <https://doi.org/10.1097/MAO.0000000000001414>
- Reinert, M. (1983). Une méthode de classification descendante hiérarchique: Application à l’analyse lexicale par contexte [A top-down hierarchical classification method: Application to lexical analysis by context]. *Les Cahiers de l’analyse des Données*, 8(2), 187–198.
- Rubin, H. J., & Rubin, I. S. (2012). *Qualitative interviewing: The art of hearing data* (3rd ed.). Los Angeles, CA: Sage.
- Sacco, G., Gonfrier, S., Teboul, B., Gahide, I., Prate, F., Demory-Zory, M., ... Guevara, N. (2016). Clinical evaluation of an over-the-counter hearing aid (TEO First®) in elderly patients suffering mild to moderate hearing loss. *BMC Geriatrics*, 16(1), 136. <https://doi.org/10.1186/s12877-016-0304-4>
- Sbalchiero, S., & Tuzzi, A. (2017). *Web scraping, topics, time and classification: Comparing methods*. Paper presented at the 2017 ITACOMS2017, Bologna, Italy.
- Seale, C., & Silverman, D. (1997). Ensuring rigour in qualitative research. *European Journal of Public Health*, 7, 379–384. <https://doi.org/10.1093/eurpub/7.4.379>
- Smith, C., Wilber, L. A., & Cavitt, K. (2016). PSAPs vs hearing aids: An electroacoustic analysis of performance and fitting capabilities. *The Hearing Review*, 23(7), 18.
- Streubert, H. J., & Carpenter, D. R. (2011). *Qualitative research in nursing: Advancing the humanistic imperative* (5th ed.). Philadelphia, PA: Lippincott, Williams & Wilkins.
- Tran, N., & Manchaiah, V. (2018). Outcomes of direct-to-consumer hearing devices for people with hearing loss: A review. *Journal of Audiology and Otology*, 22(4), 178–188. <https://doi.org/10.7874/jao.2018.00248>
- United States Congress. (2017). *Over-the-Counter Hearing Aid Act of 2017*. Retrieved from <https://www.congress.gov/bill/115th-congress/senate-bill/670?q=%7B%22search%22%3A%5B%22Over+the+Counter+Hearing+Aid+Act+of+2017%22%5D%7D&r=2>
- Valente, M., & Amlani, A. M. (2017). Cost as a barrier for hearing aid adoption. *JAMA Otolaryngology–Head & Neck Surgery*, 143(7), 647–648. <https://doi.org/10.1001/jamaoto.2017.0245>
- VERBI Software. (2017). MAXQDA 2018 [Computer software]. Berlin, Germany: Author.
- World Health Organization. (2017). *Millions have hearing loss that can be improved or prevented*. Retrieved from http://www.who.int/mediacentre/news/notes/2013/hearing_loss_20130227/en/
- World Health Organization. (2018). *Deafness and hearing loss*. Retrieved from <http://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss>
- Zeraatkar, K., & Ahmadi, M. (2018). Trends of infodemiology studies: A scoping review. *Health Information and Libraries Journal*, 35(2), 91–120. <https://doi.org/10.1111/hir.12216>