Trends in Singing Voice Research: An Innovative Approach

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Summary: Objectives. The objectives of this study were to trace and describe research patterns in singing voice, to compare the amount of published research over time, to identify journals that published most papers on "singing voice," and to establish the most frequent research topics.

Materials and Methods. The study uses qualitative and quantitative approaches through descriptive statistics, text mining, and clustering. The authors conducted a search to identify scientific papers. The titles and abstracts were analyzed regarding word frequency and relations between them, through hierarchical cluster analysis and co-occurrence networks. The frequency of journals was calculated, as well as the amount of papers across time.

Results. Since 1949, 754 papers were published and an increase was noticed. Even though 162 journals were identified by the authors, the *Journal of Voice* holds the majority of papers, in every analyzed period. An evolution of studied topics is described. Up to 2010, the main theme was professional singers, especially classical and opera interpreters. Since then, voice quality and the effects of training gathered more attention.

Conclusions. The growing interest in singing has been conspicuous since the first indexed paper. However, it has been slightly slowing down. Until 2010, great importance was given to the voice quality of singers and their occupational demands. Acoustic analysis was widely used to study the effects of training. Since 2010, the concern with functionality is increasing, rather than the organic voice structures. Musical perception studies have been a trend, as well as the use of electroglottography.

Key Words: Singing–Voice–Clustering–Text mining–Scientometry.

INTRODUCTION

Voice research and focal themes of interest have evolved across times. The demands of professional voice use currently play an important role in clinical research—and singing is no exception.[1–4] Professional voice users comprise people who depend on their voice at a high level of proficiency demands (eg, lawyers, telemarketers, actors, and singers). Singers are considered elite vocal performers among all professional voice users.[5] Compared with speech, such activity requires more endurance, flexibility, and vocal tract control.[6] There is a lot of hidden information in scientific literature that cannot be studied from a simple statistical point of view. Data mining tries to discover and interpret such information. Specifically, text mining, as an interdisciplinary approach, analyzes data in natural language text through the use of algorithms.[7–10] Clustering is a process to group words from a dataset into clusters, according to their frequency and proximity.[11] This technique finds and establishes natural groups of data elements.[12] The combination of text mining and bibliometric techniques allows the identification of unseen patterns in research fields. Bibliometrics and scientometrics are relatively unexplored from both qualitative and quantitative perspectives.[7] A bibliometric approach to research allows the quantification of studies of literature related to singing voice, promoting knowledge advancement in the field related to social and to policy questions.[13] Some limitations are known—this kind of analysis does not represent the quality of the included studies—rather, it is merely a quantity indicator. Also, this method does not allow measurement of the impact of each topic or single paper (eg, number of citations).[14] Thus, the present study sheds new light on the identification of major academic branches and research trends in singing voice. The study presented here is one of the first investigations using this technique.

This paper primarily aims to trace the history of research in singing voice. It sets out to compare the amount of published research over decades and, yearly, in the last decade. Journals are identified that published the most papers on the topic of "singing voice." Also, most recurrent research subtopics were established.

MATERIALS AND METHODS

The study uses qualitative and quantitative approaches through descriptive statistics, text mining, and clustering.

Source selection and search strategy

Authors used PubMed to conduct the search using the expression *(singing[mh] OR singer[tiab] OR singers[tiab]) AND (voice[mh] OR voice[tiab]) NOT (neoplasms[mh] OR laryngectom*[tiab])*. PubMed is a widely used free scientific search engine that provides access to references of scientific papers. To narrow the search, authors included some Medical Subject Headings terms or [mh] and limited the search to title and abstract—[tiab]. Filters to article types (clinical trial and review) and species (humans) were activated. Publication date filters were activated as needed.

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Information extraction

Results from PubMed were exported in two different ways. First, a CSV file was exported with information on indexation data. *LibreOffice 5.2.3.3* (The Document Foundation) was used to import and transform text into columns. Only columns with title, journal, year of publication and first author remained. Second, two TXT files were generated with titles and abstracts—each one for one time period (1949–2010 and 2011–2016), hereafter referred as first and second time periods, respectively.

Treatment of data

Graphics of published research distribution were generated by the previous software. Frequency tables of published research about singing voice and journals were generated by *IBM SPSS Statistics*, Version 23 (SPSS Inc., Chicago, USA).

Authors used a text mining approach to identify and compare main topics between two time intervals (from 1949 up to the end of 2010; from the beginning of 2011 up to the end of 2016). *KH Coder*, Version 3, was used to conduct semantic measures. Based on the previously described search query, information regarding titles and abstracts was retrieved from PubMed as a text file. Standard stop words provided by software were used, along with some selected by authors to exclude obvious usefulness of such information used by PubMed indexation (Appendix).

Hierarchical cluster analysis was conducted for the same periods. Such method allows finding and analyzing combinations of words with similar appearance grouped into patterns with a dendogram as a final result.[15] For this, the Ward method and Jaccard distance were used. Such an approach creates word groups that point to major themes.

Both methods transform the data into a visual representation while considering the nature of words.[13]

Co-occurrence networks of words were generated for both periods. This method presents closely associated words connected with lines.[15] The analysis was based on sentences and the filter edge was set up to 30 words. Only nouns and adjectives were analyzed. This technique allowed the detection of high-frequency words occurring together and the identification of communities. Based on this technique, graphs were created—using a color coding—to represent parts of the network that were more closely associated with each other.[15] Node sizes were set up to mirror word frequency, and edge thickness to the strength relation between words.

RESULTS

Amount of published research

The first study retrieved by the query was published in 1949. Since then, 754 research studies have been published. An analysis of publishing distribution over decades is presented in Table 1.

Figure 1 represents the amount of research published per year in the last decade, representing 45.32% of the total amount since the beginning.

TABLE 1.
Distribution of Published Research About Singing Voice Over Decades

Years	Number of Papers
2011-present	225
2001–2010	259
1991–2000	116
1981–1990	60
1971–1980	28
1961–1970	27
1949–1960	39
Total	754

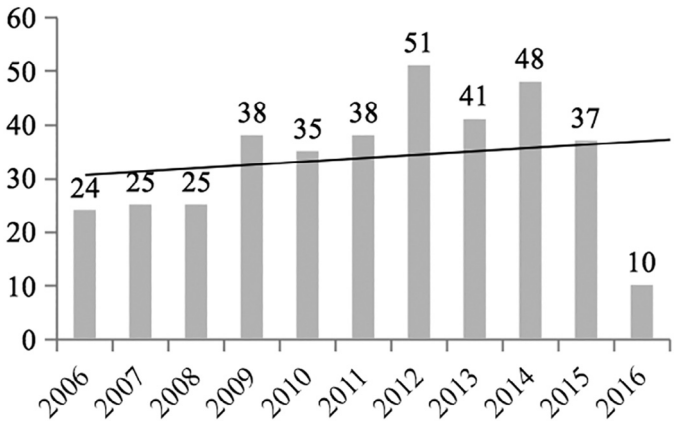

FIGURE 1. Distribution of published research on singing over the last decade with linear forecast trend line. Number of publications per publication year.

Journals that published most papers

Since 1949, 162 journals published studies on singing. Research of the last decade (2006–2016) was published in 82 different journals. A ranking of journals was created, taking into account the number of published papers. In both periods, the *Journal of Voice* published the largest number of studies, as seen in Tables 2 and 3.

TABLE 2.
Top 10 Journals on Singing Research (From 1949 to the End of 2005)

Journal	Frequency	%
1. *Journal of Voice*	108	28.3
2. *Folia Phoniatrica (Basel)*	30	7.9
3. *Revue De Laryngologie - Otologie - Rhinologie*	22	5.8
4. *The Journal of the Acoustical Society of America*	17	4.5
5. *Folia Phoniatrica Et Logopaedica*	16	4.2
6. *Vestnik Otorinolaringologii*	16	4.2
7. *Logopedics, Phoniatrics, Vocology*	15	3.9
8. *Journal of Speech and Hearing Research*	8	2.1
9. *The Laryngoscope*	7	1.8
10. *HNO*	6	1.6

Most frequently researched subtopics

In Figure 2, both periods show six clusters that correspond to the same number of cuts in the tree, at about level 1.1 (observed value). The bars on the left side of the colored dendrogram shown in Figure 2 indicate the term frequency of each word. The dendogram generated for the first time period (Figure 2A) revealed six different groups. The first group shows that "singer" was frequently near "professional." Thus, professional singer is considered the first main theme. "Opera" was the word most related to professional singer.

In the second group, "voice" was the most frequently used word appearing mainly related to "quality," so this is the second main theme. In turn, voice quality was related to "change" and "register." The expression "vocal function" was related to "performance." Other words from this cluster suggest the analysis of acoustic parameters related to singing ("acoustic analysis," "vibrato," and "formant") and training influence on laryngeal muscles ("training," "year," "laryngeal," and "muscles"). The third cluster shows the highly frequent word "pitch" related to "range," thus considered as the third main theme. The fourth cluster is composed by fundamental frequency, on its own. The fifth cluster is about classical singing, mirroring the importance given by scientific community to that genre of singers.

For the second time period, the dendogram (Figure 2B) also revealed six different groups. The first cluster also relates the high-frequency word "voice" to "quality," considered as the first main theme. However, in this period, an emphasis was given to training effect. The second cluster's most common word was "singer," also related to "professional"—thus, the second main theme. The presence of the "control group" expression suggests that there were more studies with clinical relevance and evidence. Musical perception is also a trend

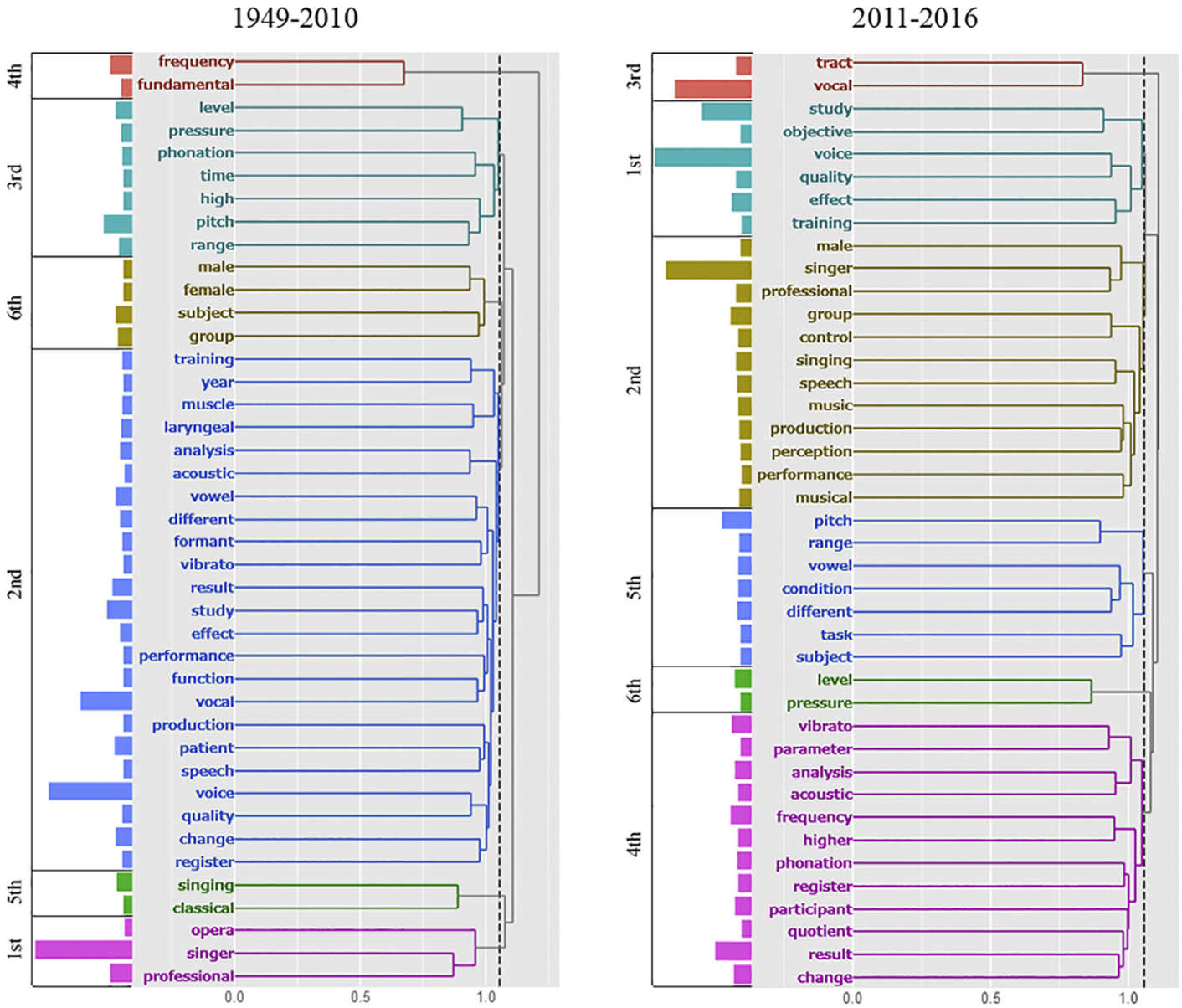

FIGURE 2. Hierarchical cluster analysis for titles and abstracts: (**A**) 1949–2010, (**B**) 2011–2016.

TABLE 3.
Top 10 Journals on Singing Research (From the Beginning of 2006 to 2016).

Journal	Frequency	%
1. *Journal of Voice*	152	40.9
2. *Logopedics, Phoniatrics, Vocology*	37	9.9
3. *The Journal of the Acoustical Society of America*	32	8.6
4. *Folia Phoniatrica Et Logopaedica*	13	3.5
5. *PLoS One*	9	2.4
6. *Revue De Laryngologie - Otologie - Rhinologie (Bord)*	7	1.9
7. *HNO*	6	1.6
8. *Jornal Da Sociedade Brasileira De Fonoaudiologia*	5	1.3
9. *Vestnik Otorinolaringologii*	5	1.3
10. *Annals of the New York Academy of Sciences*	4	1.1

in the second cluster. The third cluster contains only "vocal tract," and the fourth cluster is composed of acoustic and electroglottographic analysis.

Co-occurrence networks (Figures 3 and 4) reveal 41 most frequent words for each time period. Between 1949 and 2010, different communities were identified. The first community (light green) is identified by biggest nodes, representing highest frequency words "singer" and "voice." Professional is close to the first, with a thicker edge revealing a strong connection between them. "Female" and "male" are present, although just the first is connected to "classical" and "singing." "Voice" is related to "patient" and "quality," which reveals high interest in the clinical standpoint. The red community can be pointed out as the second one, because of its dual connection to the first. "Vocal" and "function" are very close to each other. "Year" and "training" are also in that community. The blue community is the third, as it has four edges to three different communities: including "fundamental frequency," "vibrato," and "formant." The yellow community is the fourth as it has three edges to two different communities and includes words related to glottal competence. The fifth community is the orange one, including "pitch," "range," and "change"; the "high" word is also connected to pitch. The sixth community is the purple one, not directly related to any other community, but intercepted by one edge. This includes the words "study," "effect," and "acoustic analysis," revealing that most studies used such assessment method and analyzed effects. The most unrelated community was the green one, as the seventh, mirroring some isolated importance given to laryngeal musculature.

Between 2011 and 2016, six communities were identified. The first one (yellow) includes the most frequent words, also connecting "singer" to "voice" and "vocal." The second community

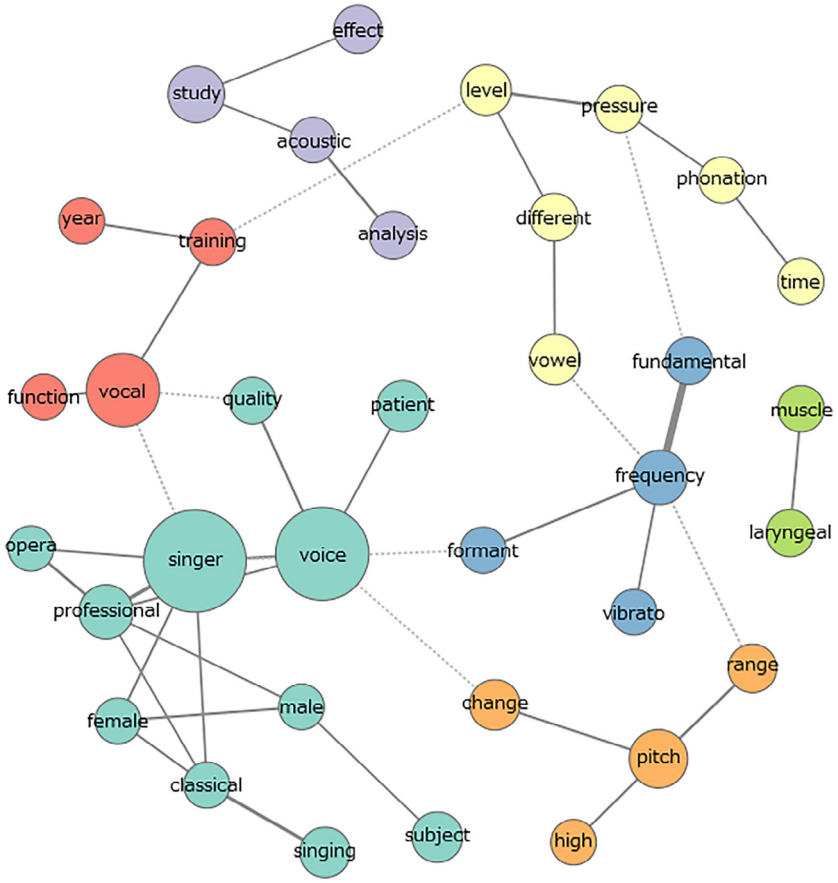

FIGURE 3. Co-occurrence network from titles and abstracts (1949–2010).

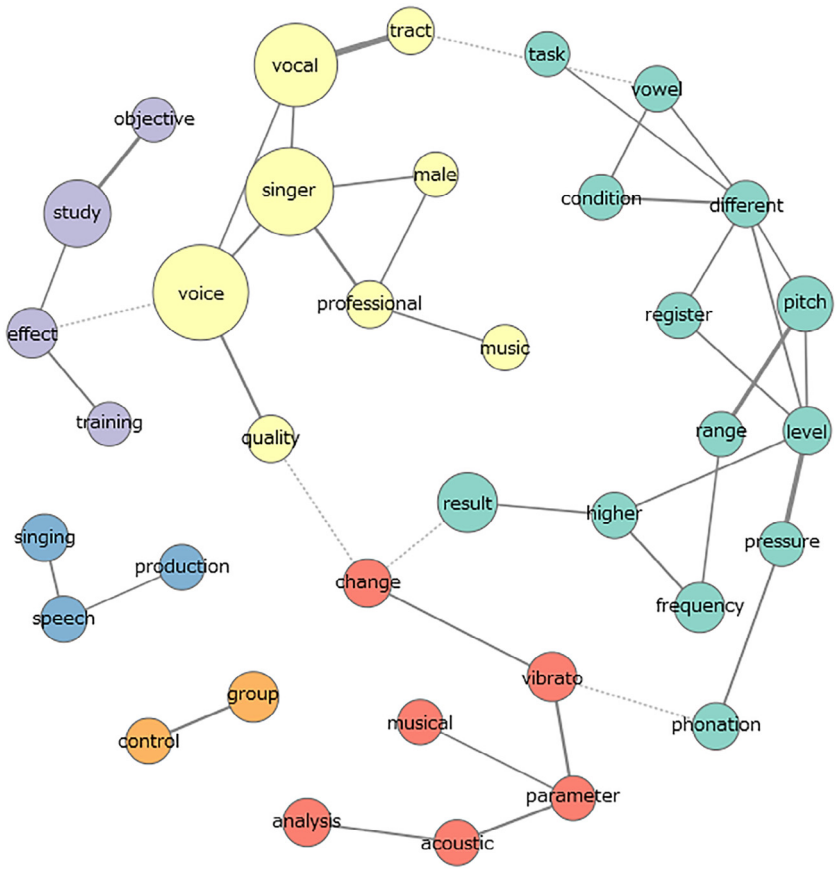

FIGURE 4. Co-occurrence network from titles and abstracts (2011–2016).

has scattered words, although "pitch range" and "pressure level" are central words and are close to each one. The red community is the third because it connects to two communities. Purple is the fourth, denoting the study of "training effects." The remaining communities' order is not clear. One relates "speech production" to "singing," whereas the other has "control" and "group," suggesting a higher usage of such clinical research methodology.

DISCUSSION

The interest in singing has been conspicuously growing since the first indexed paper in PubMed was published in 1949. However, since the apogee in 2012, it has been slightly slowing down. An abrupt decrease was noticed in 2016, even though the search was conducted during the last days of that year—maybe due to the not yet completed indexation of PubMed. The linear forecast trend line indicates a slight positive tendency of such growth, except the last 2 years.

In the journal ranking, the *Journal of Voice* was the most prolific for both time periods.

It is interesting to note that *Jornal da Sociedade Brasileira de Fonoaudiologia* came into the list in the last decade, as it is published in Portuguese. Another two non-English written journals were found in both lists—*Vestnik Otorinolaringologii*, Russia, and *HNO*, Germany.

Until 2010, the dominating topic was the professional singer, mainly opera singers. Great importance was given to the voice quality of singers and to their occupational demands. During this period, "pitch range" received great attention, as well as "acoustic analysis." Classical singing was frequently under study. Fundamental frequency, vibrato, and formants were the most studied characteristics.

From 2010 up to 2016, the research focus underwent slight changes. Voice quality related to training effect received more attention, suggesting that concern with functionality is increasing, against organic structure in the first period. Also, researchers are looking more into the function rather than the subject. In the last decade, it was possible to notice that male singers were studied more. In this epoch, studies seem to be more clinical. Musical perception and electroglottography emerged as trend topics in this period.

CONCLUSIONS

This is a brief paper that summarizes almost all of the research that has been conducted over time. Although it is a relatively new topic in scientific research, the field of singing voice has evolved rapidly. The number of papers published annually has increased steadily, as well has the clinical relevance of singing. The present study presents an innovative approach for the study of this field, with both bibliometric and scientometric

approaches. Also, it provides an overview and a comparison of research trends. The topics studied in this field have changed across time.

The authors limited their search to PubMed because of time restrictions. This approach can add a certain bias, because it indexes publications from life sciences and biomedical fields; therefore, some scientific papers can be missing. A selection bias can also be considered when these research approaches are used. Some of the reported topics can appear out of its original context, which induces interpretation errors. Even though publication count is one of the most used indicators, it can be criticized because it reveals the quantity and not the quality of the publications. In the future, it is recommended to include more search engines to cover other fields. The number of analyzed words was limited on purpose, so the interpretation could be done—future researchers can use other selection methods. Another type of methodological approach could be adopted, so the validity and precision can be achieved. It would be relevant to reproduce this research in every decade, so that history and trends could be easily traced.

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APPENDIX

Stop words and expressions used to filter results

index
author
%
jjvoice
doi
/
publish
rights
reserve
copyright
electronic
address
significant
difference
datum
j.jvoice
information
methods
method
conclusion
conclusions
introduction
objectives
f