Megaron, Vol. 19, No. 2, pp. 138–151, June 2024

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/megaron.2024.04307

MEGARON

Article

A systematic approach to sound and spatial experience studies: Detection of the key concepts and themes

Emir ÇEKMECELIOĞLU[1,*], Çiğdem POLATOĞLU[2]

[1]*Department of Architecture, Hatay Mustafa Kemal University, Hatay, Türkiye*
[2]*Department of Architecture, Yıldız Technical University, İstanbul, Türkiye*

ARTICLE INFO

Article history
Received: 20 March 2024
Accepted: 11 June 2024

Key words:
Aural experience; sound; sound studies; sound-space; spatial experience.

ABSTRACT

The research examines studies about the process of spatial experience and highlights aural interactions. In this sense, the goal is to assess and describe the expanding corpus of literature in the field of sound and spatial experience and to provide a framework for further investigation.
Key concepts and themes that emerge at the intersection of space, sound, and experience are examined through a comprehensive review. Bibliometric research techniques are applied with a methodological framework in accordance with the process of detecting themes. Web of Science database was used as the raw data source, and scientific mapping and analysis of the obtained data was performed using VOSviewer. PRISMA guidelines were utilized for the study's document selection, and reporting processes.
Systematic scanning and selection processes resulted in the collection of 416 documents. The procedure of detecting themes led to the identification of 13 major themes and 136 key concepts that emerged. Essentially, it was discovered that the "soundscape" was the most significant concept and theme in the field of study. Furthermore, assessments and inferences were conducted on all other key concepts and themes. The major components of the field, concentrated areas, and potential development areas have been discovered through the analysis of conceptual relationship networks.
The findings will provide future researchers an opportunity to comprehend how the research field has developed, as well as a chance to learn more about new potential fields of study and enhance their research.

Cite this article as: Çekmecelioğlu, E., & Polatoğlu, Ç. (2024). A systematic approach to sound and spatial experience studies: Detection of the key concepts and themes. Megaron, 19(2), 138–151.

INTRODUCTION

How do we experience our environment? This question has long been one of the most important ones in environmental studies. To address this and raise concerns about the mechanisms underlying spatial experience, the senses were organized in a hierarchy, with vision generally recognized as the superior sense (Clouten, 1973; Hutmacher, 2019; Levin, 1993; Posner et al., 1976; Spence, 2020). The "eye-centric paradigm" manifests the superiority ascribed to vision in architectural culture. This method, which peaked with modernist philosophy, aimed to design the space in the logic of machine aesthetics based on a utilitarian system, ignoring the physical and psychological connections of humans with the space (Bille & Sørensen, 2018; Pallasmaa, 2005; Rybczynski, 2001; Williams, 1980).

***Corresponding author**
*E-mail adres: emircekmeceli@gmail.com
This manuscript is produced from a doctoral dissertation.

However, the users experience the space in an interactive and responsive way with their entire body rather than developing a one-dimensional relationship with it based on the mind's vision. This interaction results from the user's relationship with the environment via all sense mechanisms (Merleau-Ponty, 1968; Pallasmaa, 2005; Puderbaugh, 1967). Especially the aural features of space play a vital role in the experiential identity since they go far beyond serving as a simple, neutral background (Sheridan & Van Lengen, 2003).

Similar questions have always existed in concepts about the experience of space, and the role of sound in the processes of spatial experience has long garnered attention. Pythagoras is credited with using the concepts of harmonic music in his spatial reasoning as early as the fifth century BC (Long, 2006; Pallasmaa, 2017). These concepts are supported at this time period by ancient structures like Greek amphitheaters and whispering galleries (Sheridan & Van Lengen, 2003). In the Middle Ages, the stern and echoing interiors of monasteries and cathedrals expressed notions about approaches to auditory experience (Rasmussen, 1964). The Renaissance brought about more systematic ideas about how geometry affects how sound travels across space, and later on, this system became apparent in concert halls (Forsyth, 1985). With Sabine's acoustic theory, this interaction was conceptually named for the first time in 1895, and it thereafter started to emerge in the literature (Sabine, 1906; Sheridan & Van Lengen, 2003). With the exception of the Philips Pavilion, this strategy did not receive much support within the eye-centric paradigm of the modernist era (Xenakis & Kanach, 2008). Since the advent of acoustic science, the literature has started to reflect a greater variety of methods. The term "soundscape," initially introduced by Southworth in 1967 and then systematized by Schafer, is described as the acoustic environment that humans experience in context (Kang et al., 2016; Schafer, 1994; Southworth, 1967). The International Standardization Organization (ISO) standardized this concept in 2014, and it is still referenced in the literature today (ISO, 2014). Another modern conceptual concept is called "Aural Architecture," which came into being after the 2000s and is defined as architecture that expresses the characteristics of a place that can be experienced by hearing (Blesser & Salter, 2007).

It is observed that there are few research studies in the field that comprehensively and methodically review this literature. Zhang & Kang (2007) conducted a non-systematic literature review focusing on the concept of soundscape in urban open spaces and systematized the factors affecting it. Brown (2011) provided a quick overview of the methodologies as well as an explanation of the fundamental terms and concepts related to soundscape and soundscape planning. Fowler (2013) questioned the concepts related to sound and aurality within architecture and sound design approaches, briefly introduced some prominent approaches in the literature, and evaluated them mutually in the context of installations. Again, Fowler (2015) discussed the interaction of space and sound studies and architectural design processes and compared the leading theories in the literature. The argument made in the paper is that by integrating these methodologies into the architectural design processes, the experience potential of the space will grow. A review by Bild et al. (2016) examined several perspectives on user interaction and the auditory environment in public spaces using a non-systematic literature review methodology. Aletta et al. (2016) analyzed the soundscape descriptors in the literature and offered a conceptual framework for creating predictive models. Ma et al. (2018) reviewed studies that used a systematic approach to evaluate the human perceptual dimensions of sound. They identified perceptual dimensions that are included in the studies and referred to the general judgment of a person. Erfanian et al. (2019) examined the physio-psychological measurement parameters used in soundscape studies with a systematic review. It revealed the trends of the parameters used in the studies. In a systematic review of soundscape prediction model techniques, Lionello et al. (2020) compared various modeling approaches and conducted content analysis on 22 publications. Li & Lau (2020) carried out a systematic literature review to investigate the impacts of audio-visual interaction on soundscape evaluation, design, and noise control. They analyzed and categorized the publications in the field for their study, which resulted in a paper that can be used as a manual for other studies. A systematic literature analysis by Yang & Jeon (2020) analyzed the effects of building envelope elements in the urban acoustic environment and drew conclusions about building envelope design strategies. With a systematic review, Engel et al. (2021) identified the usage of psychoacoustic parameters in soundscape studies from the previous ten years as well as broader trends in the area. Pellegatti et al. (2023) carried out a systematic literature review on the connection between ventilation system-related noises and students' acoustic comfort by concentrating on the indoor soundscape of classrooms. Kang (2023) reviewed and highlighted the most recent advancements and discoveries in the field of soundscape with all of its different facets.

The majority of the research under consideration had a basic methodology and worked under constrained parameters. Few current studies apply bibliometric techniques in a systematic way. However, none of these studies examined the field as a whole, identified the key concepts in the field and the thematic areas they developed, or documented the current condition of the field from this perspective at the time of the study. Therefore, a systematic literature review that considers all approaches emerging at the intersection of space-experience-sound will provide valuable potential for the field. To achieve this, the study uses bibliometric analysis techniques to conduct a systematic and comprehensive review of the literature that is forming at the nexus of sound, space, and experience. The field's emerging concepts and themes they generate are recognized, and their potential for further research is evaluated. Finding conceptual linkages within the field allows us to deduce probable development areas and areas of concentration. The study's evaluation procedures made it possible to pinpoint key concepts and themes within the context of sound and spatial experience, identify current trends, and identify new, pertinent research areas for future studies.

MATERIALS AND METHODS

Research Questions

The study is shaped in line with two main research questions:

- What key concepts emerge in sound and space experience studies and the thematic areas created by these concepts?
- Which themes have studies focused on over time in relation to sound and spatial experience? What is the distribution of these themes in the literature? Which concepts and themes are newer and more open to research?

The primary research question aims to investigate the place of sound and auditory in the user's spatial experience processes, and especially to explore the concepts and themes emerging in this field. The second question aims to evaluate the key concepts and themes that emerge, explore their distribution in the literature and relations between them, and thus derive implications for the future provision of the study field.

Methodological Structure: Detection of Themes

The term bibliometrics was first used by Pritchard (1969) and is defined as the science that aims to quantitatively evaluate academic outcomes developed in a field. It discusses several quantitative techniques for analyzing and evaluating texts and information, particularly those stored in large bibliographic data sets. In recent years, bibliometric research methods have also been widely used in the disciplines of architecture and built environment research (Bild et al., 2016; Engel et al., 2021; Erfanian et al., 2019; Ganbat et al., 2018; H. Li & Lau, 2020; X. Li et al., 2017; Y. Li et al., 2018; Lionello et al., 2020; Xue et al., 2018; Zhao et al., 2018).

A structured approach based on the bibliometric techniques was developed to address the study's research goals. First, in order to identify the concepts and themes that address the processes of sound and spatial experience, a system based on the "process of detecting themes" proposed by Cobo et al. (2011a) was planned. The study proposed a five-step process in order to detect and visualize the conceptual particular themes or general thematic areas in a research field. Thus, it allows us to quantify the importance of themes and thematic areas within a field of study, and their contribution to the field:

1. Collection of raw data: The process of obtaining raw data sets by scanning in databases.
2. Selection of the type of item to analyze: The process of descoping raw data based on filters such as journals, articles, authors, descriptive terms, or words and obtaining an appropriate dataset.
3. Extraction of relevant information from the raw data: At this stage, the co-occurrence frequencies of keywords according to the research field are extracted from the corpus of documents by counting the number of documents in which the two keywords occur together.
4. Calculation of similarities between items based on the extracted information: Based on the data obtained in the third stage, the similarities between the items are calculated based on the co-occurrence frequencies of the keywords (association strength (Coulter et al., 1998; Van Eck & Waltman, 2007).
5. Use of a clustering algorithm to detect the themes. It is based on a process of clustering to locate subgroups of keywords that are strongly linked to each other with several clustering algorithms.

Database

In bibliometric studies, bibliographic sources such as Web of Science (WOS), Scopus, Google Scholar, Microsoft Academic, PubMed, and Dimensions are used (Chen, 2017; Moral-Muñoz et al., 2020). Among these databases, WOS covers different formats such as full-text articles, reviews, editorials, chronologies, abstracts, papers (journal and book-based), and technical articles. In terms of temporal scope, it contains over 90 million records from 1900 to the present. With these aspects, it is widely accepted as a high-quality digital database (Ding & Yang, 2022; Moral-Muñoz et al., 2020). In addition, the WOS Core Collection database is considered the most authoritative data source as it contains the most respected and influential journals (Pouris & Pouris, 2011; Song et al., 2016; Zhao et al., 2018). These factors led to the selection of WOS as the study's bibliometric database.

SMA Software

SMA is used to perform the third (co-occurrence frequencies of keywords), fourth (calculation of similarities), and fifth steps (clustering process) in the method of detecting themes. In order to select the appropriate tool for the study, papers that compare and contrast SMA software were examined (Cobo et al., 2011b; Gutiérrez-Salcedo et al., 2018; Markscheffel & Schröter, 2021; Moral-Munoz et al., 2019; Moral-Muñoz et al., 2020; Pan et al., 2018). Although there isn't a consensus among the studies, each one has explained the benefits and drawbacks of SMA tools and stated that picking the best software based on the analysis techniques to be used and, in some cases, combining more than one software will produce advantageous results. The prevalence of use was also analyzed by Pan et al. (2018), who found that VOSviewer software was most commonly used despite finding an upward trend in the use of all the software they looked at. The VOSviewer software is used in the study with its ability to work with common databases (Moral-Muñoz et al., 2020), to create successful visualization outputs (Markscheffel & Schröter, 2021; Moral-Muñoz et al., 2020), and to use the association strength (Van Eck & Waltman, 2007; 2010) similarity criteria in accordance with the method of detecting themes and to be suitable for clustering algorithms.

The results of the methodological analysis are also reported in accordance with PRISMA guidelines (Liberati et al. 2009) (Figure 1).

RESULTS

Search Strategy and Selection Criteria

Keywords for searches were chosen in accordance with the study's objectives and research questions in order to get relevant data from the database. The words "sound," "space," and "experience" were entered into the WOS Core Collection database [(((ALL=(sound)) AND ALL=(space)) AND ALL=(experience))]. At this stage, limitations such as year range or document type were not applied in order to keep the scope wide. As a result of this search, raw data was collected by accessing 2274 records.

First, 2206 records were collected after the results were filtered as English-language materials. The first screening of these documents was made according to their relevance to the research area. Since the keywords used in the search have synonyms in space sciences, health sciences, computer sciences, physics, mathematics, mechanics, etc., documents that are unrelated to the research topic have been eliminated. Then, all records were examined according to their titles, keywords, and abstracts, and incompatible records were eliminated. These stages led to the elimination of 1782 studies that had no relation to the scope. In particular, studies in multidisciplinary fields such as acoustics

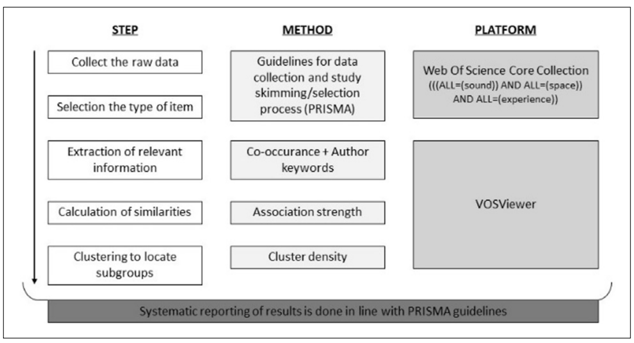

Figure 1. Summary of methodological structure.

were examined, and records unsuitable for the study were excluded. Following a full-text evaluation of 424 records, 8 papers and book chapters also included in article versions were dropped from the data set. In the end, 416 studies were acquired for the systematic review process (Figure 2).

Descriptive Analysis

The "process of extraction of relevant information from the raw data" was started with 416 records. First, information on document types and distribution by years was gathered using the WOS system's capabilities in order to define the dataset's current state.

The 416 records' document types revealed that they were made up of 350 articles, 40 proceedings, 14 book chapters, and 12 review articles. The study's coverage of a variety of document types offers an expanded perspective.

When the number of documents changes over time is analyzed, it can be shown that the documents published from 1991 to the present are covered in the scope (Figure 3). It can be said that the number of documents in the study field has increased rapidly, especially since the 2000s. Similarly, it is understood that the number of citations has increased significantly. The statistics indicate that there is increasing interest in the field. Additionally, it can be inferred from Figure 3 that the majority of the documents examined are recent studies.

Thematic Analysis

Data on 416 documents were downloaded from the WOS database in "plain text file" format and with the scope of "full record and cited references." The text file was imported into VOSviewer to conduct next-stage analyses. As stated in the third step of the process of detecting themes, in order to analyze the frequency of co-occurrence of keywords, the file was subjected to Co-occurrence - Author Keywords analysis, and the process was run according to the frequency of co-occurrence of the two words. It was found that there were singular-plural and synonymous words among the occurring words (e.g., sound and sounds; sound-art and sound art; urban park and urban parks; bird sound and bird song, etc.). When these words were matched with a "thesaurus" file and the same procedure was repeated, it was determined that 136 out of a total of 1126 keywords exceeded the threshold. Each of these resulting keywords is considered as a concept for the field of study.

These terms were then normalized using the association strength criteria (Van Eck & Waltman, 2007), as explained in the fourth phase of the process. As a result, keyword relationship networks were created, and a total of 482 connections between 136 keywords emerged. Some keywords may occur in multiple documents, in which case there is a stronger link between them than one. This indicates that the association strength of the two keywords is higher.

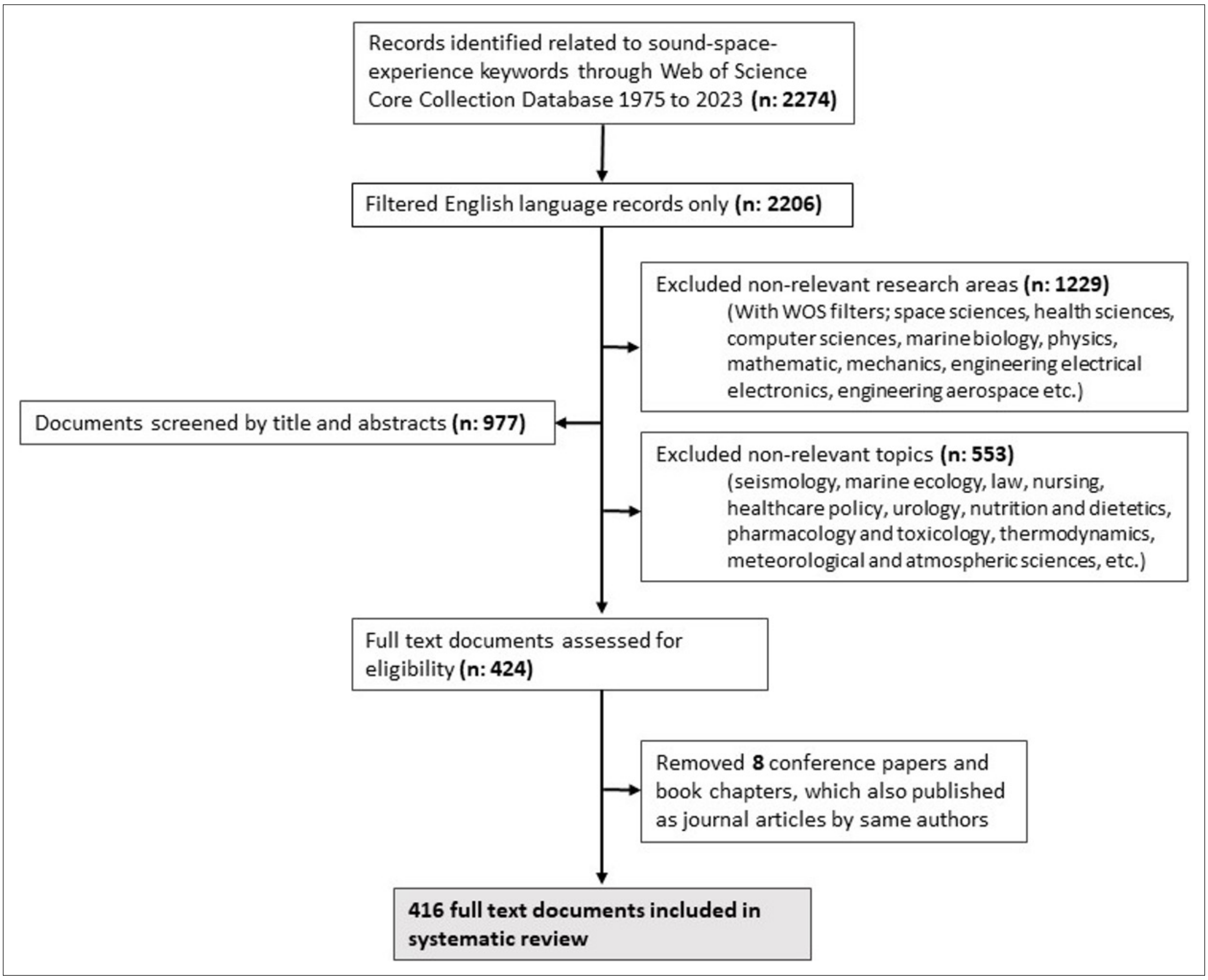

Figure 2. PRISMA Flow diagram for the paper search and skimming/selection process, December 2023.

When evaluated in this way, the total link strength within the network turns out to be 570.

In accordance with the clustering process, which is the last step of the process of detecting themes, the process was run with the clustering algorithm of the VOSviewer (Waltman et al., 2010) and 13 clusters were obtained.

The data obtained as a result of the processes run in the VOSviewer software are presented digitally with an interactive system where graphics and texts are processed together. In order to present this data in text and make mutual assessments, the interactive data has been transferred and presented in a table form by the author. The occurring keywords, clusters, their occurrences (Occ.), total link strength (TLS), and average publication years (APY) are shown in Figure 4.

According to Callon et al. (1991), keyword clusters and their interconnections are obtained using co-word analysis. These resulting clusters are considered themes. Each thematic network is tagged using the name of the most important keyword (by occurrence value) in the associated theme. For example, the keyword "blindness," which has the highest occurrence and TLS value in cluster 1, stands out as the most important item in the cluster and gives its name to the cluster. Therefore, the themes that emerged within the database are blindness, virtual reality, sound perception, urban space, perception, soundscape, noise, public space, music, listening, sound art, inequality, and sound. In order to make comparisons between these themes, the total occurrence, TLS, and APY data of each cluster were also calculated.

The Network Visualization Map (NVM) presents the resulting keywords and the connections between them in detail (Figure 5). The elements depicted as circles and labels on the NVM represent keywords. The size of the circle increases with a keyword's frequency of occurrence. Connections between keywords are expressed as links. The line thickness of the link between two keywords increases as the association strength between them becomes stronger. Since the system is operated with the co-occurrence anal-

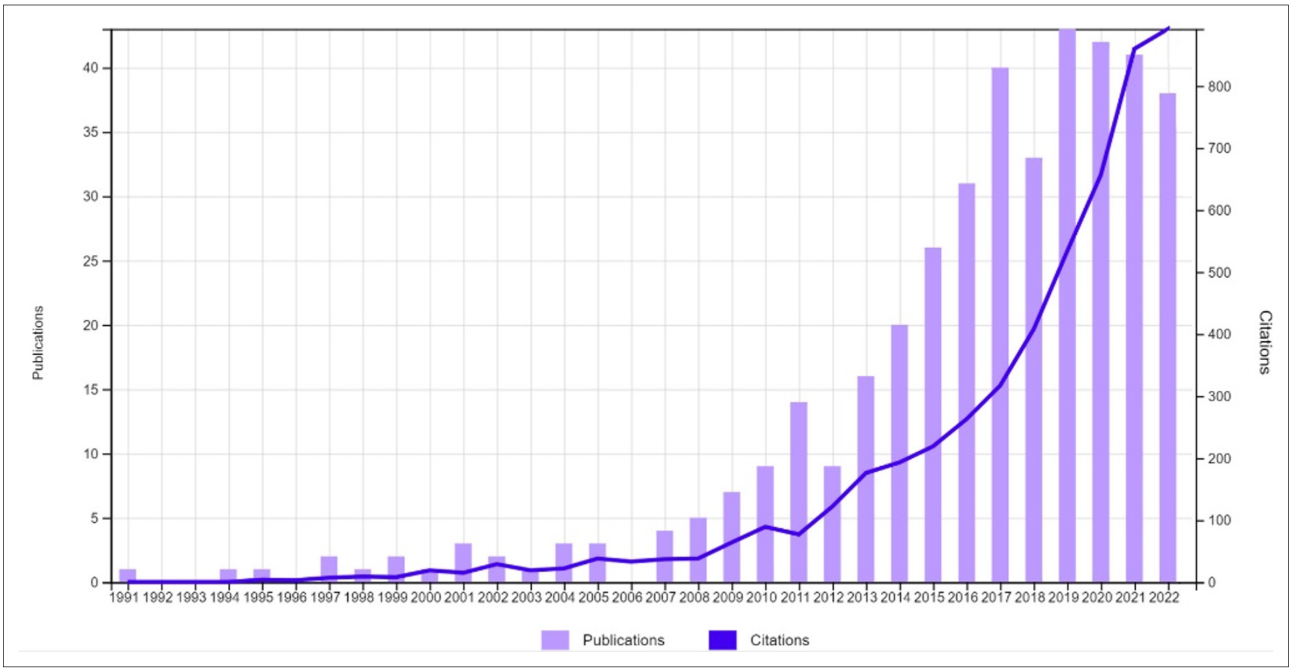

Figure 3. Times cited and publications over time graph.

ysis type, the association strength and therefore the link thickness increases as the number of publications in which the two keywords occur together increases. In the NVM, keywords in the same cluster are represented by circles of the same color (Van Eck & Waltman, 2023). The color legend of the clusters was created by the author and added to the graph (Figure 5).

When the NVM is examined, it can be seen that the keyword "soundscape" is the most dominant element in the research field in terms of both occurrence and TLS. As seen in Figure 4, the keyword soundscape occurred 52 times and TLS is 97. Similarly, the most common words after the keyword “soundscape” (Occ: 52, TLS: 97) with occurrence and TLS; “sound” (Occ: 27, TLS: 55), “public space” (Occ: 11, TLS: 29), “urban design” (Occ: 11, TLS: 26), and “noise” (Occ: 10, TLS: 26) continue as follows. The occurrence of the words following these five most common keywords does not change in direct proportion to the TLS. For example, the sixth most common keyword according to occurrence is "urban space" (Occ: 10, TLS: 19); according to the TLS, the sixth strongest keyword is “music” (Occ: 9, TLS: 23). Therefore, it is seen that each keyword emerges within a different network of relationships (Figure 5).

Connection relationships between items can be seen from the NVM graph. For example, the items most frequently linked to the keyword "soundscape" are: “urban park” (Link Strength: 5), “public space” (LS: 5), “sound” (LS: 4), “acoustic environment” (LS: 4), and “noise” (LS: 4). The links between an item and its associated items and a different item and its associated items create attraction and repulsion layouts within the graph. It is seen that keywords and clusters more closely related to each other are intertwined, and keywords with weak connections are located in distant parts. For example, the keyword "inequality" and its surrounding keywords are only associated with a single connection to "soundscape," and are located far outside the chart as they do not associate with other items. On the contrary, the keywords "soundscape" and "public space" are very close to each other due to their strong connections (Figure 5).

The NVM graph can also be used to gather details about clusters and their connections. As exemplified, since the level of connection between the "inequality" (Cluster 12) and "soundscape" (Cluster 6) clusters is weak, the clusters are located at distant points; due to the intense relationship between the "soundscape" (Cluster 6) cluster and the "public space" (Cluster 8) cluster, the clusters are intertwined. Through mutual assessments using NVM and Figure 4, comparisons between the number of items and the occurrence of clusters can also be conducted. For example, although it has the highest number of items, the occurrence of the items in the "blindness" (Cluster 1) is lower than the "soundscape" (Cluster 6) and "virtual reality" (Cluster 2) clusters. When the TLS is examined, the "blindness" (Cluster 1) comes after the "soundscape" (Cluster 6), "virtual reality" (Cluster 2), and "perception" (Cluster 5) clusters, despite the highest number of items. Due to this feature, the more peripheral location of the "blindness" (Cluster 1) is understood in the graph (Figure 5).

The Cluster Density Visualization Map (CDVM), which displays the cluster density and inter-cluster interactions, is shown in Figure 6.

Cluster 1 (20 item)			
keyword	**Occ**	**TLS**	**APY**
auditory cortex	2	4	2015,00
auditory localization	2	3	2017,00
auditory perception	5	9	2015,80
auditory system	2	5	2000,50
binaural	3	8	2015,00
blindness	7	14	2015,29
body representation	2	2	2018,50
deafness	2	2	2017,00
hearing	2	4	2011,50
perceptual dimensions	2	3	2018,00
perceptual learning	2	5	2015,00
peripersonal space	2	4	2015,00
plasticity	4	10	2008,00
psychoacoustics	2	3	2019,50
sound localization	3	8	2007,67
space perception	2	4	2008,00
spatial cognition	2	5	2016,00
spatial hearing	5	12	2016,00
tool-use	2	4	2015,00
visually impaired	5	9	2017,00
Blindness	**58**	**118**	**2014,04**

Cluster 2 (19 item)			
keyword	**Occ**	**TLS**	**APY**
acoustic comfort	5	8	2021,40
acoustic environment	5	14	2019,00
archaeoacoustics	2	3	2016,50
architectural acoustics	3	4	2012,33
auralization	4	6	2019,00
church acoustics	2	3	2016,50
cultural heritage	2	3	2018,50
emotion	7	12	2018,43
gesture	3	5	2016,00
heritage acoustics	2	1	2021,00
multisensory	4	5	2016,50
parametric design	2	1	2012,00
resonance	2	2	2021,00
room acoustics	3	4	2019,67
spatial audio	2	3	2017,00
speech intelligibility	3	6	2020,67
subjective evaluation	3	3	2020,33
virtual acoustics	2	5	2016,50
virtual reality	9	19	2019,11
Virtual reality	**65**	**107**	**2017,97**

Cluster 3 (15 item)			
keyword	**Occ**	**TLS**	**APY**
acoustic design	2	5	2012,00
auditory semantics	2	2	2011,50
ethnography	3	5	2022,00
experience	4	11	2017,25
grounded theory	2	2	2021,00
health	3	11	2019,67
improvisation	2	4	2019,00
indoor soundscape	4	8	2019,50
long-term care	2	6	2019,00
multimodal integration	2	1	2019,50
phenomenology	2	4	2019,50
silence	5	4	2017,20
sound perception	5	12	2018,00
sound quality	4	7	2013,75
well-being	3	7	2017,00
Sound perception	**45**	**89**	**2017,72**

Cluster 4 (13 item)			
keyword	**Occ**	**TLS**	**APY**
attention	4	8	2017,5
attunement	2	6	2019,5
audio-visual interaction	2	4	2019,5
everyday life	2	6	2014,5
heritage	2	4	2020,5
landscape	4	10	2017,5
landscape architecture	2	6	2018
memory	6	9	2016,67
place	4	6	2017,75
sensory experience	4	9	2019,75
sonic experience	3	9	2019,67
tranquillity	2	5	2017,5
urban space	10	19	2018,1
Urban space	**47**	**101**	**2018,19**

Cluster 5 (13 item)			
keyword	**Occ**	**TLS**	**APY**
affect	6	17	2015,83
color	2	4	2014
ecology	2	5	2016,5
embodiment	4	10	2015
perception	9	20	2019,11
performance	4	11	2015,5
politics	2	5	2017
semiotics	2	4	2017
sound-space	2	6	2022
space	7	18	2017
synesthesia	4	10	2017,75
touch	2	3	2019
voice	3	9	2015
Perception	**49**	**122**	**2016,98**

Cluster 6 (12 item)			
keyword	**Occ**	**TLS**	**APY**
acoustic experience	2	1	2021,5
bird sounds	2	6	2021,5
eeg	2	3	2021,5
green space	3	2	2018,33
nature	2	2	2018
noise annoyance	3	4	2019
soundscape	52	97	2018,19
soundscape assessment	4	6	2018,75
soundwalk	4	10	2017,5
traffic noise	5	13	2021,6
urban park	10	16	2018,8
urban soundscape	5	7	2019,6
Soundscape	**94**	**167**	**2019,52**

Cluster 7 (9 item)			
keyword	**Occ**	**TLS**	**APY**
built environment	2	7	2022
covid-19	4	13	2020,75
cycling	2	7	2022
mobility	3	7	2013
noise	10	26	2017,3
noise perception	2	8	2019,5
post-occupancy evaluation	2	2	2022,5
residential satisfaction	2	2	2023
survey	2	8	2013
Noise	**29**	**80**	**2019,23**

Cluster 8 (9 item)			
keyword	**Occ**	**TLS**	**APY**
ambisonics	2	5	2020
atmosphere	2	4	2019
pocket park	3	12	2020
public space	11	29	2019,09
quality of the urban public experience	2	9	2020
restoration	2	6	2020,5
soundscape design	5	21	2017,6
urban design	11	26	2018,18
urban sound planning	3	12	2017,33
Public space	**41**	**124**	**2019,08**

Cluster 9 (9 item)			
keyword	**Occ**	**TLS**	**APY**
accessibility	2	2	2020
architecture	8	18	2015,25
art	2	4	2015,5
city	3	8	2019,33
culture	2	5	2019
music	9	23	2018,78
sonic environment	4	7	2020,5
sound preference	2	5	2013,5
technology	3	7	2018
Music	**35**	**79**	**2017,76**

Cluster 10 (6 item)			
keyword	**Occ**	**TLS**	**APY**
aesthetics	4	5	2018,25
anthropology	2	6	2017
aural architecture	3	12	2018
jerusalem	2	4	2013,5
listening	7	11	2015,57
sound studies	5	16	2015
Listening	**23**	**54**	**2016,22**

Cluster 11 (5 item)			
keyword	**Occ**	**TLS**	**APY**
acoustics	2	7	2015,5
design	2	9	2018
field recording	3	2	2016,33
museums	2	5	2021,5
sound art	6	12	2015
Sound art	**15**	**35**	**2017,27**

Cluster 12 (3 item)			
keyword	**Occ**	**TLS**	**APY**
inequality	2	2	2019,5
noise pollution	2	1	2019,5
sensory ethnography	2	2	2020,5
Inequality	**6**	**5**	**2019,83**

Cluster 13 (3 item)			
keyword	**Occ**	**TLS**	**APY**
bells	2	1	2014,5
sense of place	3	3	2019,67
sound	27	55	2017,63
Sound	**32**	**59**	**2017,27**

Figure 4. Detailed List of Items and Clusters (prepared by the author).

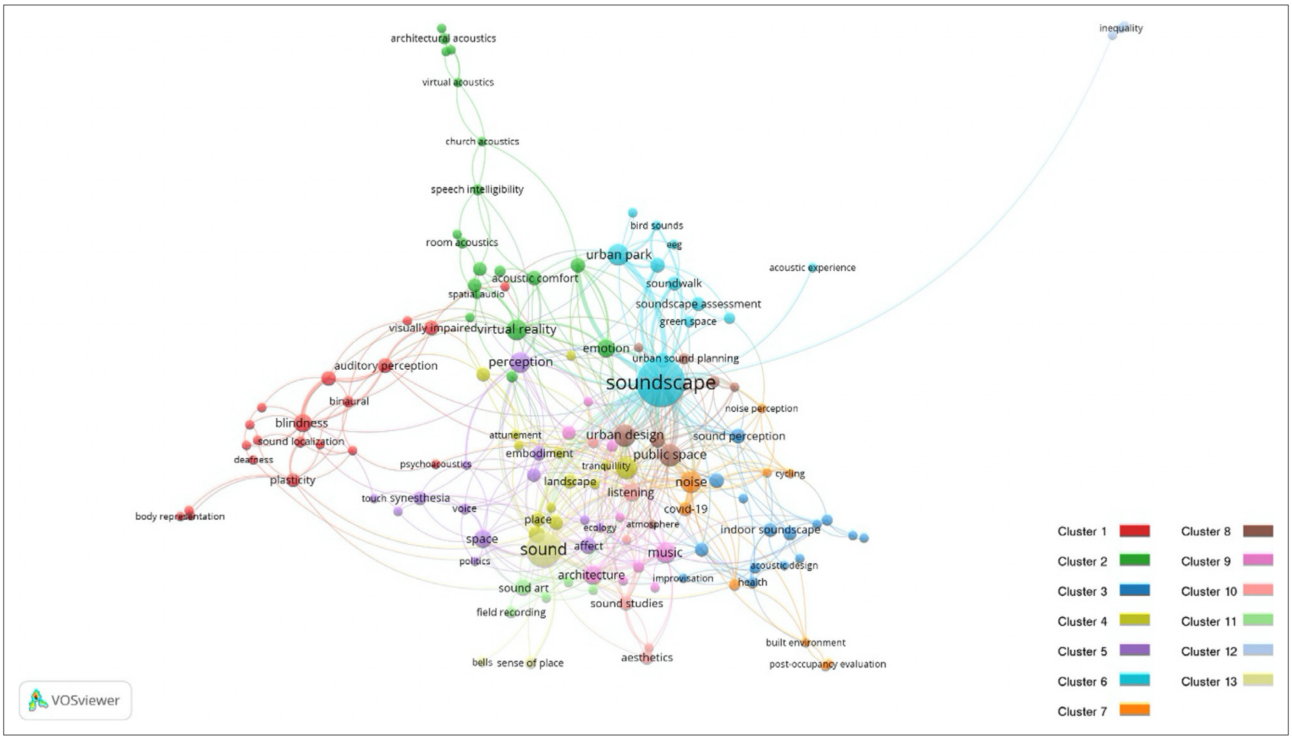

Figure 5. Network visualization map (NVM).

The "soundscape" component and the dominance of Cluster 6 can be seen clearly in the CDVM, similar to the NVM (Figure 5). As mentioned in the inferences from NVM, the location of the "blindness" (Cluster 1) at the periphery can be seen. The "virtual reality" (Cluster 2) has a weak relationship with other clusters, as can also be shown. It is evident that the "inequality" (Cluster 12) is situated entirely independently. The "urban space" (Cluster 4), "noise" (Cluster 7), "public space" (Cluster 8), "music" (Cluster 9), and "listening" (Cluster 10) clusters are in a very thick association, particularly in the center of the graph, and these clusters are mixed with one another in most of the network. On the basis of this, it can be claimed that the fields of study found inside these clusters are also interconnected.

The last presented graph is the Overlay Visualization Map (OVM) (Figure 7). OVM is a version of the NVM colored according to the average publication years (APY) of items. Similar to NVM, this map also includes keywords represented by circles with occurrence value-based sizing and links with association strength-based sizing. In contrast, there is no coloring for the clusters on this map. Each keyword is colored on the map according to the APY of the publications where it appears in the database. The legend displays this color distribution (Van Eck & Waltman, 2023) (Figure 7).

Inferences regarding the concepts' recentness can be drawn with the help of OVM. A keyword, for instance, is considered less current in the field if it has a low occurrence value and an older APY. A keyword that has a high occurrence value and a recent APY, however, is considered to be quite contemporary. Additionally, a keyword with a low occurrence value and a recent APY is likely an idea that is still being researched in the field and could be a potential field for expansion.

According to OVM, the keywords retrieved through systematic analysis have, on average, been in the database since 2000 and some of the elements are still effective today. The APY value for publications containing the keyword "soundscape" is 2018.19, for instance. This result demonstrates that the keyword "soundscape" is often used in the database and has recently grown in importance as a field of study. Another example of the inferences is the "auditory system"'s occurrence value is 2, the TLS value is 5, and the APY is 2000.50. These results indicate that this keyword was only used in the database's initial years and wasn't used subsequently. As a result, the keyword has a low level of currentness. Conversely, the keyword “traffic noise” has an occurrence value of 5, a TLS value of 13, and an APY value of 2021.60. These findings indicate that "traffic noise" is a more recent concept than "auditory system" and represents a potential field for database progress. Within OVM, similar to the keyword “traffic noise”; “cycling” (Occ: 2, TLS: 7, APY: 2022), “EEG” (Occ: 2, TLS: 3, APY: 2021.50), and “museums” (Occ: 2, TLS: 5, APY: 2021.50) keywords can be considered as current and potential areas of progress (Figure 7).

The OVM graph does not directly provide information

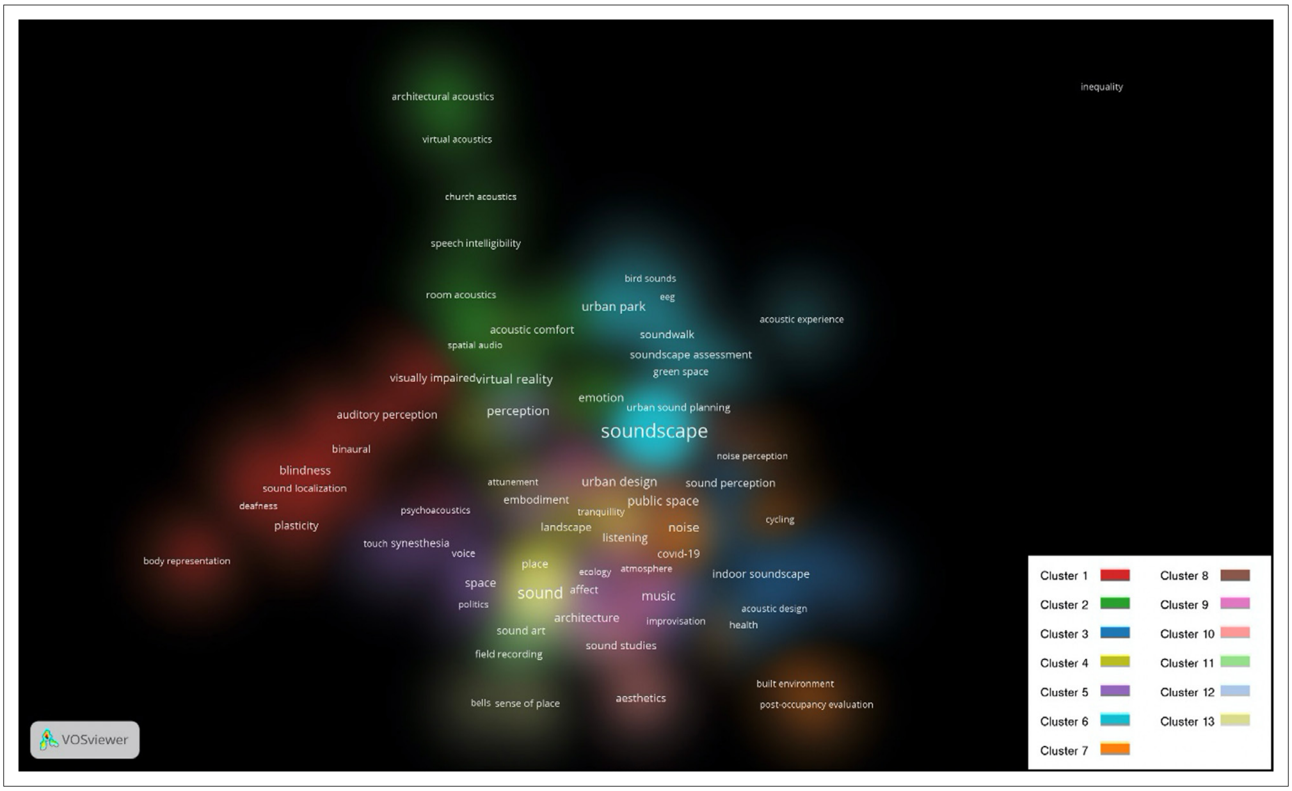

Figure 6. Cluster density visualization map (CDVM).

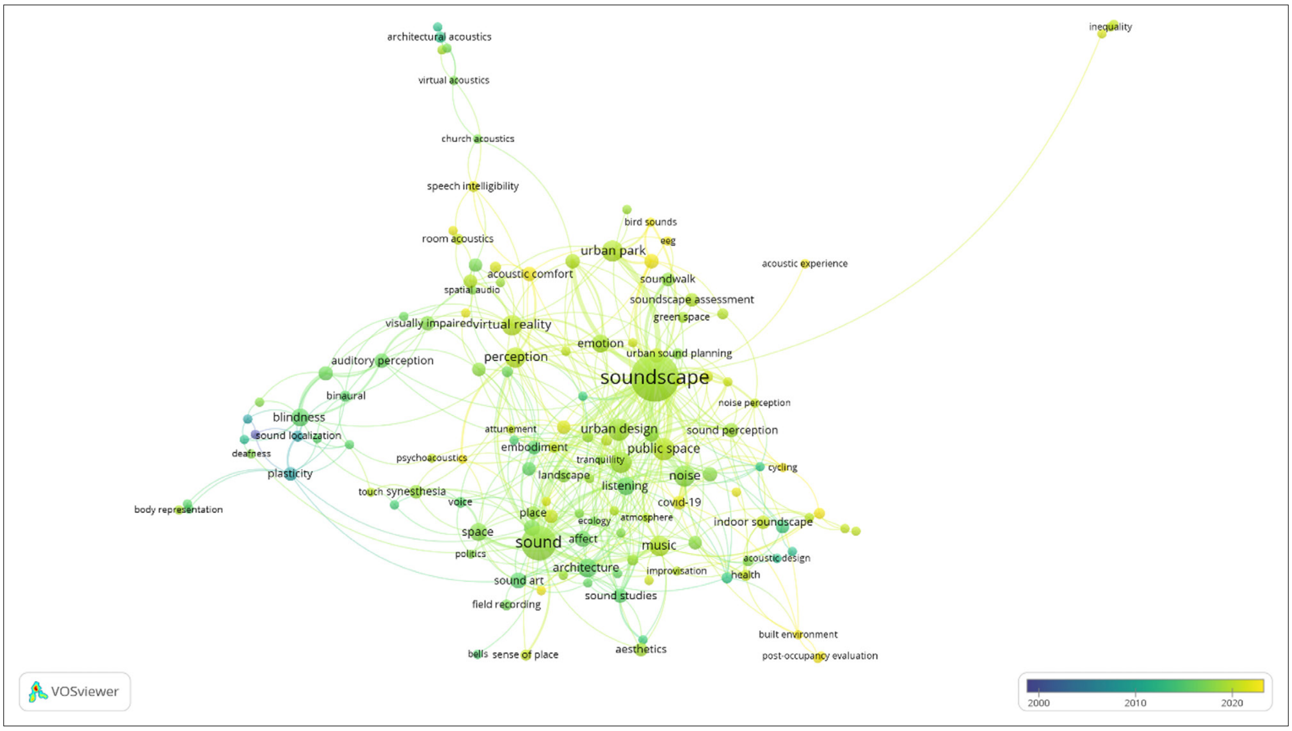

Figure 7. Overlay visualization map (OVM).

about clusters. To make inferences about clusters, the arithmetic mean of APY values of all keywords in a cluster was calculated by the author. Accordingly, it was seen that the cluster with the oldest APY was "blindness" (Cluster 1; APY: 2014.04). This is followed by “listening” (Cluster 10, APY: 2016.22) and “perception” (Cluster 5, APY: 2016.98). The cluster with the most recent APY in the field is "inequality" (Cluster 12, APY: 2019.83). Following this cluster, "soundscape" (Cluster 6, APY: 2019.52) and "noise" (Cluster 7, APY: 2019.23) appear respectively (Figure 4, Figure 7).

DISCUSSION

Evaluation of Themes

In the third section, binary inferences were drawn about both the items and the clusters based on the evaluation of Figures 4,5,6 and 7. In order to gain comprehensive results, it would be helpful to discuss all of these data at once, especially in regard to the themes.

First, it can be shown from Figures 4-5 and 6 that "soundscape" (Cluster 6; Occ: 94, TLS: 167) has the highest values for total occurrence and TLS out of all the themes. With the help of this information, it is simple to conclude that "soundscape" is covered in the majority of database research and has the strongest connections to all other fields. The "soundscape" has emerged as the most popular and up-to-date theme within the research field, when these data are evaluated along with the APY. In particular, with the recent APY (2019.52), occurrence (Occ: 94), and TLS (167) values, it is clear that this theme has become increasingly important. With all of these characteristics, it is possible to say that the "soundscape" theme will continue to have an effect as a prospective theme within the field and will be a potential area for further research with new concepts it will be associated with.

The "blindness" theme is identified as a significant theme in terms of its occurrence and TLS within the field (Cluster 1; Occ: 58, TLS: 118). The theme has a diverse range of studies, as was seen when the APY values were evaluated (e.g. "auditory system," APY: 2000.50; "psychoacoustics," APY: 2019.50), but it is less included in the database than in previous years (total APY: 2014.04). Consequently, it can be claimed that its popularity has dropped.

The evaluation of the "virtual reality" theme reveals that it is significant in terms of occurrence and TLS (Cluster 2; Occ: 65, TLS: 107), and that it is still relevant to the items it contains in terms of the APY value (APY: 2017.97). It is one of the field's key themes, especially given that it involves features connected to architectural acoustics.

Examining the "perception" theme reveals that it has a TLS value that is significantly higher than the value of occurrence (Occ: 49, TLS: 122). This can be explained by the items' prevalence, and it is also seen in the theme's centrality in the NVM and CDVM graphics (Figures 5, 6). It is clear that the theme has a wide distribution when considered with the APY value (APY: 2016.98). Examining the "public space" and "urban space" themes reveals how closely related their occurrence and TLS values are to the "perception" theme and how centric their graphic placements are as well. On the other hand, it might be claimed that the themes are more current because their APY values ("public space": 2019.08; "urban space": 2018.19).

The "sound perception" theme is ranked in the middle in terms of total occurrence and TLS when it is examined (Cluster 3; Occ: 45, TLS: 89). In terms of its graphic position and connections, it can be noticed that it has a closer connection to the "soundscape" theme than it does to the others (Figure 6). When compared according to APY (2017.72), it can be said that it has an average value.

When the "music" and "noise" themes are compared, it can be seen that they have similar TLS values, occurrence rates, and graphic positions (Figure 6). It is clear from APY values that the "noise" theme is one of the field's most recent themes, whereas the "music" theme has a declining value (Figure 4).

Although "sound," "listening," and "sound art" are perceived as lower-ranking themes in terms of occurrences and TLS values, this is understandable given the low number of items. These themes also have similar features in terms of APY values.

The "inequality" theme's characteristics, which make it seem to be the weakest theme with occurrence value, TLS value, and graphic position in the database, can be explained by the fact that it has the newest APY value (APY: 2019.83). These characteristics suggest that this theme might be an exciting potential for progress in the field. The relationships, degree of use, and relevance of the concepts and themes that emerged within the study field were made clear through the analyses. The result of the research included an analysis of these, looking at their linkages, present status, and occurrence in the literature. Findings concerning the studied area's current state and predictions about future changes were drawn by this analysis.

A future study will see that the most important concept and theme in the field is "soundscape." In line with the results of the study, it will be seen how the concepts and themes to be investigated are included in the literature, which concepts are more closely associated with previous studies—and which are less associated or not. Future researchers will be able to narrow the focus of their research using the knowledge they gain about lesser-known concepts and themes in the field. For instance, researchers who study "traffic noise" will discover that this concept occurs five times in the research field and is linked to nine other concepts 13 times ("acoustic comfort": 1, "acoustic environment": 1, "bird sounds": 2, "noise annoyance": 1, "soundscape": 3, "soundscape assessment”: 1, “urban park”: 2, “perception”: 1, “public space”: 1). They will find that the concept has an APY value of 2021.60 and is still current in the field. They will be able to evaluate how the concept is located in the "soundscape" theme and how it relates to other components. For example, it can be inferred that a study to be carried out by including the keyword "EEG," which is within the same theme but is not directly related, may be a potential topic. For each of the 136 concepts and 13 themes found in the study, similar conclusions can be drawn. Regarding these aspects, it is believed that the data from the study made a special contribution to the advancement of the field.

EVALUATION AND CONCLUSION

Using bibliometric analysis methodologies, a comprehensive and systematic assessment of the literature was carried out for the study, with an emphasis on the auditory experience processes of the space. The purpose of this review was to define the key concepts that emerged in the literature on sound and space experience studies as well as the themes that arose from their combination.

First, descriptive information about the documents gathered after the systematic scanning process is presented. As a result, it has been noted that there is a general upward trend in the field of study. VOSviewer software was used to perform co-occurrence and co-keyword analyses on the documents. As a result, 136 final keywords have emerged as widely used basic concepts in the field of study. All data related to these concepts have been digitized and presented with detailed tables and graphs.

Then, the concepts were categorized according to their occurrence, and the connections between them were determined according to their association strength. With the clustering algorithm, these concepts were divided into clusters, and thematic areas in the study field were determined. Thirteen themes were identified in this regard: blindness, virtual reality, sound perception, urban space, perception, soundscape, noise, public space, music, listening, sound art, inequality, and sound.

To determine which thematic areas were concentrated in the studies and which areas were new and open to research, mutual evaluations were conducted with all the data acquired throughout this procedure. According to these evaluations:

- It turned out that "soundscape" was the most effective concept that emerged in the field of study. The concept of soundscape appears to be dominant, both in terms of frequency of occurrence and the total link strength with others. However, soundscape also has a current date among all concepts in terms of the average publication year. Therefore, it can be clearly said that its impact will continue in future studies within the field.
- After the "soundscape" concept, it was revealed that the concepts of "sound," "public space," "urban design," and "noise" were the other most common concepts in the study area, respectively.
- In studies, the concept of "soundscape" is most frequently associated with the concepts of "urban park" and "public space." From this perspective, it is apparent that these concepts are frequently studied as research subjects together.
- It appears that "inequality" and "sensory ethnography" are the concepts with the weakest connection to the field of study. It may be argued that the term "sensory ethnography" is relatively new to the field of study, particularly considering how recently the average publishing year has occurred. It follows that this might be a possible subject for future research in the field.
- Examining the thirteen themes that emerged from the study, it is discovered that the "soundscape" theme is the most prevalent. The average publication year value of the items included in the soundscape theme is also quite up-to-date compared to other themes. Consequently, it is evident that the thematic area's dominance and the concepts it contains will persist into the future of this field of study.
- It seems that the concept of "traffic noise" is the most current concept within the soundscape theme. As a result, it is evident that recent research has focused on this idea within the theme and that it will continue to influence subsequent research.
- Other themes that emerged after the soundscape theme are listed according to their prevalence as blindness, virtual reality, perception, public space, urban space, sound perception, music, noise, sound, listening, sound art, and inequality. Evaluations related to these themes are also presented.
- The theme of "inequality" has emerged as the most recent and least prevalent theme in the field of study. Given how current it is and the limited amount of existing research, this theme area may prove to be an intriguing topic for future investigation within the field of study.

The results presented above can be extended for all key concepts and themes, along with the outcomes provided by the research. The study enabled the identification of important concepts and themes in the field regarding the sound and spatial experience framework, revealed trends in the field, and contributed to the discovery of new related research areas. Consequently, a future study using this document will be able to rapidly assess how the concepts or themes coming under its scope are covered in the literature, which concepts or themes are more closely related, and which are less closely correlated. In addition, researchers will have the opportunity to gain knowledge about potential progress areas in the field and deepen their research.

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

REFERENCES

Aletta, F., Kang, J., & Axelsson, Ö. (2016). Soundscape descriptors and a conceptual framework for developing predictive soundscape models. Landsc Urban Plan, 149, 65–74.

Bild, E., Coler, M., Pfeffer, K., & Bertolini, L. (2016). Considering sound in planning and designing public spaces: A review of theory and applications and a proposed framework for integrating research and practice. J Plan Lit, 31(4), 419–434.

Bille, M., & Sørensen, T. F. (2018). Atmospheric architecture: Elements, processes and practices. In D. Howes (Ed.), Senses and sensation: Critical and primary sources (pp. 137–154). Bloomsbury Academic.

Blesser, B., & Salter, L. R. (2007). Spaces speak, are you listening?: Experiencing Aural Architecture. MIT Press.

Brown, A. L. (2011). A review of progress in soundscapes and an approach to soundscape planning. Int J Acoust Vib, 17(2), 73–81.

Callon, M., Courtial, J. P., & Laville, F. (1991). Co-word analysis as a tool for describing the network of interactions between basic and technological research: The case of polymer chemistry. Scientometrics, 22(1), 155–205.

Chen, C. (2017). Science Mapping: A Systematic review of the literature. J Data Inf Sci, 2(2), 1–40.

Clouten, N. H. (1973). On visual perception of a spatial environment. Archit Sci Rev, 16(4), 178–187.

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. (2011a). An approach for detecting, quantifying, and visualizing the evolution of a research field: A practical application to the fuzzy sets theory field. J Informetr, 5(1), 146–166.

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. (2011b). Science mapping software tools: Review, analysis, and cooperative study among tools. J Am Soc Inf Sci Tech, 62(2), 1382–1402.

Coulter, N., Monarch, I., & Konda, S. (1998). Software engineering as seen through its research literature: A study in co-word analysis. J Am Soc Inf Sci, 49(13), 1206–1223.

Ding, X., & Yang, Z. (2022). Knowledge mapping of platform research: A visual analysis using VOSviewer and CiteSpace. Electron Commer Res, 22(3), 787–809.

Engel, M. S., Fiebig, A., Pfaffenbach, C., & Fels, J. (2021). A Review of the use of psychoacoustic indicators on soundscape studies. Curr Pollut Rep, 7(3), 359–378.

Erfanian, M., Mitchell, A. J., Kang, J., & Aletta, F. (2019). The psychophysiological implications of soundscape: A systematic review of empirical literature and a research agenda. Int J Environ Res Public Health, 16(19), 3533.

Forsyth, M. (1985). Buildings for music: The architect, the musician, and the listener from the seventeenth century to the present day. MIT Press.

Fowler, M. (2013). Sound, aurality and critical listening: Disruptions at the boundaries of architecture. Archit Cult, 1(1), 159–178.

Fowler, M. (2015). Sounds in space or space in sounds? Architecture as an auditory construct. Archit Res Q, 19(1), 61–72.

Ganbat, T., Chong, H. Y., Liao, P. C., & Wu, Y. Di. (2018). A bibliometric review on risk management and building information modeling for international construction. Adv Civil Eng, 2018(1), 8351679.

Gutiérrez-Salcedo, M., Martínez, M. Á., Moral-Munoz, J. A., Herrera-Viedma, E., & Cobo, M. J. (2018). Some bibliometric procedures for analyzing and evaluating research fields. Appl Intell, 48(5), 1275–1287.

Hutmacher, F. (2019). Why is there so much more research on vision than on any other sensory modality? Front Psychol, 10, 2246.

ISO. (2014). Acoustics - soundscape part 1: Definition and conceptual framework. https://www.iso.org/standard/52161.html

Kang, J. (2023). Soundscape in city and built environment: current developments and design potentials. City Built Environ, 1, 1.

Kang, J., Aletta, F., Gjestland, T. T., Brown, L. A., Botteldooren, D., Schulte-Fortkamp, B., Lercher, P., van Kamp, I., Genuit, K., Fiebig, A., Bento Coelho, J. L., Maffei, L., & Lavia, L. (2016). Ten questions on the soundscapes of the built environment. Build Environ, 108, 284–294.

Levin, D. M. (1993). Modernity and the hegemony of vision (1st ed.). University of California Press.

Li, H., & Lau, S. K. (2020). A review of audio-visual interaction on soundscape assessment in urban built environments. Appl Acoust, 166, 107372.

Li, X., Wu, P., Shen, G. Q., Wang, X., & Teng, Y. (2017). Mapping the knowledge domains of building information modeling (BIM): A bibliometric approach. Autom Constr, 84, 195–206.

Li, Y., Lu, Y., Taylor, J. E., & Han, Y. (2018). Bibliographic and comparative analyses to explore emerging classic texts in megaproject management. Int J Project Manag, 36(2), 342–361.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. PLoS Med, 6(7), e1000100.

Lionello, M., Aletta, F., & Kang, J. (2020). A systematic review of prediction models for the experience of urban soundscapes. Applied Acoustics, 170, 107479.

Long, M. (2006). Architectural acoustics. Elsevier Academic Press.

Ma, K. W., Wong, H. M., & Mak, C. M. (2018). A systematic review of human perceptual dimensions of sound: Meta-analysis of semantic differential method applications to indoor and outdoor sounds. Build Environ, 133, 123–150.

Markscheffel, B., & Schröter, F. (2021). Comparison of two science mapping tools based on software technical evaluation and bibliometric case studies. COLLNET J Scientometrics Inf Manage, 15(2), 365–396.

Merleau-Ponty, M. (1968). The visible and the invisible. Northwestern University Press.

Moral-Muñoz, J. A., Herrera-Viedma, E., Santisteban-Espejo, A., & Cobo, M. J. (2020). Software tools for conducting bibliometric analysis in science: An up-to-date review. Prof Inform, 29(1), e290103.

Moral-Munoz, J. A., López-Herrera, A. G., Herrera-Viedma, E., & Cobo, M. J. (2019). Science mapping analysis software tools: A review. In W. Glänzel, H. F. Moed, U. Schmoch, & M. Thelwall (Eds.), Springer handbook of science and technology indicators (pp. 159–185). Springer Publishing.

Pallasmaa, J. (2005). The eyes of the skin: Architecture and the senses. John Wiley & Sons Inc.

Pallasmaa, J. (2017). Touching the world – Vision, hearing, hapticity and atmospheric perception. Proceeding of the Invisible Places: Sound, Urbanism and Sense of Place, Portugal, 15–29.

Pan, X., Yan, E., Cui, M., & Hua, W. (2018). Examining the usage, citation, and diffusion patterns of bibliometric mapping software: A comparative study of three tools. J Informetr, 12(2), 481–493.

Pellegatti, M., Torresin, S., Visentin, C., Babich, F., & Prodi, N. (2023). Indoor soundscape, speech perception, and cognition in classrooms: A systematic review on the effects of ventilation-related sounds on students. Build Environ, 236, 110194.

Posner, M. I., Nissen, M. J., & Klein, R. M. (1976). Visual dominance: An information-processing account of its origins and significance. Psychol Rev, 83(2), 157–171.

Pouris, A., & Pouris, A. (2011). Scientometrics of a pandemic: HIV/AIDS research in South Africa and the world. Scientometrics, 86, 541–552.

Pritchard, A. (1969). Statistical bibliography or bibliometrics. J Doc, 25(4), 348–349.

Puderbaugh, H. (1967). Physiology and communication in architecture. Archit Sci Rev, 10(3), 99–104.

Rasmussen, S. E. (1964). Experiencing architecture. MIT Press.

Rybczynski, W. (2001). The look of architecture. Oxford University Press.

Sabine, W. C. (1906). Architectural acoustics. Proc Am Acad Arts Sci, 42(2), 51–84.

Schafer, R. M. (1994). The soundscape: Our sonic environment and the tuning of the world. Destiny Books.

Sheridan, T., & Van Lengen, K. (2003). Hearing architecture: Exploring and designing the aural environment. J Architl Educ, 57(2), 37–44.

Song, J., Zhang, H., & Dong, W. (2016). A review of emerging trends in global PPP research: Analysis and visualization. Scientometrics, 107(3), 1111–1147.

Southworth, M. F. (1967). The sonic environment of cities. [Unpublished Master Thesis]. MIT.

Spence, C. (2020). Senses of place: Architectural design for the multisensory mind. Cogn Res Princ Implic, 5, 46.

Van Eck, N. J., & Waltman, L. (2007). Bibliometric mapping of the computational intelligence field. Int J Uncertain Fuzziness Knowl Based Syst, 15(05), 625–645.

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84, 523–538.

Van Eck, N. J., & Waltman, L. (2023). VOSviewer manual (1.6.19). https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.19.pdf

Waltman, L., van Eck, N. J., & Noyons, E. C. M. (2010). A unified approach to mapping and clustering of bibliometric networks. J Informetr, 4(4), 629–635.

Williams, A. R. (1980). The urban stage: A reflexion of architecture and urban design. San Francisco Center for Architecture and Urban Studies.

Xenakis, I., & Kanach, S. E. (2008). Music and architecture: architectural projects, texts, and realizations. Pendragon Press.

Xue, X., Wang, L., & Yang, R. J. (2018). Exploring the science of resilience: Critical review and bibliometric analysis. Nat Hazards, 90(1), 477–510.

Yang, W., & Jeon, J. Y. (2020). Design strategies and elements of building envelope for urban acoustic environment. Build Environ, 182, 107121.

Zhang, M., & Kang, J. (2007). Towards the evaluation, description, and creation of soundscapes in urban open spaces. Environ Plann B Plann Des, 34(1), 68–86.

Zhao, X., Zuo, J., Wu, G., & Huang, C. (2018). A bibliometric review of green building research 2000–2016. Archit Sci Rev, 62(1), 74–88.