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Bibliometrical and Visualized Analysis of Neuroaesthetics Research: A Review Based on CiteSpace

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This article analyzes the evolution of neuroaesthetics research, through 145 articles on topics related to "neuroaesthetics" derived from the Web of Science Core Collection from 1991 to 2018, uses CiteSpace to visualize the spatial distribution of publications, and analyzes outbreaks of keywords and highly cited references. The article tracks changes in the subject of neuroaesthetics, and identifies new trends in neuroaesthetics research. The article finds that the first period (1994-2005) of neuroaesthetics research focuses on the definition and scope of the field, and the value of the subject. The second period (2006-2018) mainly uses relevant experimental methods to focus on the two aspects which neuroaesthetics derives. Our research results show that this is a practice-oriented discipline. With the diversification of research methods and the distribution of academic groups around the world as shown by the survey network, international cooperation has become more and more extensive and in depth. Thus, the study of neuroaesthetics is promoted.

Keywords: neuroaesthetics, bibliometrics, CiteSpace, citation analysis, network analysis

Introduction

Modern Western aesthetics focuses on discussion of metaphysics, but with the rise of positivism and cognitive science, scientists began to pay attention to the cognitive field (Berlyne, 1974; Martindale & Moore, 1988, pp. 661-670; Seely, 2012; Aharon et al., 2001; Cinzia & Vittorio, 2009, pp. 682-687). In addition, the development of brain science in the 1980s laid a solid foundation for the field of cognitive aesthetic. By the 1990s, due to the unique research of some neuroscientists (Zeki & Lamb, 1994, pp. 607-636; Ramachandran, 2012), an increasing number of scholars gradually realized that neuroscience could provide a bridge between science structures and communication of art. They use artists' immortal works as subjects to learn more about the nature of the human mind, and they hope to explain the artistic influence of outstanding masters like Rembrandt or Picasso. Scientists believe that any adjective used to describe art, ambiguous words, such as "beautiful" and "elegant" should be theoretically and have its associated neural counterparts (Zeki, 1999). Neuroscientists hope to reveal the "universal laws" contained in paintings or sculptures and discover the basic principles to every great visual art work.

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Neuroaesthetics was firstly defined by Zeki and Lamb (1994, pp. 607-636). In his representative work "An Exploration of Art and the Brain" and related research papers, neuroaesthetics is a subject studying the neural mechanism of aesthetics experience. The goal of the study of aesthetic neural mechanism is to acquire the knowledge of the neural mechanism related to aesthetic activities, specifically the brain regions activated by aesthetic activities and their mutual relations. Zeki thought, art is an extension of the brain of vision. At present, neuroaesthetics mainly develops from two aspects. One is that some neuroscientists, such as Zeki began to explain the functional division of the brain from an artistic perspective (Zeki & Bartels, 1998, pp. 1911-1914; Solso, 2001, pp. 31-34; Goel & Grafman 2000, pp. 415-436; Chatterjee, 2003). These neuroscientists proposed and established an explanatory framework for the regulation mechanism of the brain's nerves during human aesthetic activities, and then they further elaborated and explained the interrelationship between the brain functional regions (Chatterjee, 2003; Zeki, 2013; Leder, Belke, Oeberst, & Augustin, 2004, pp. 489-508; Jacobsen, 2010, pp. 184-191). They believe human can discover the universal law and basic principles of art, the aesthetic experiences brought by no matter what kind of aesthetic vocabulary, such as "beauty" and "ugly", or the art work, such experiences have human specific nerves corresponding to it. The second aspect is to re-recognize the aesthetic theory from the perspective of neuroscience, to test and explore the existing aesthetic theory based on experiments.

Neuroaesthetics mainly uses several methods to conduct experimental observations to draw experimental conclusions, which are pathological methods, the behavioral method, electrophysiological methods, and imaging methods. The pathology method is to observe the brain regions related to artistic creation by observing the artists with brain damage. The behavioral method, which observes the viewer's aesthetic activities and preferences, interprets it from the perspectives of psychology and sociology. Electrophysiological methods mainly use the characteristics of event-related potentials and high technical time resolution to investigate the Electroencephalography (EEG) activity during the aesthetic activities, thus explaining the processing time of the neural mechanism of aesthetic activities. The imaging method mainly compensates for the low spatial resolution of the enterprise resource planning (ERP) technology and the rough location of the brain region. In addition, the technical means commonly used in the experiences are mainly positron emission tomography (PET), magnetic resonance imaging (MRI), and fMRI (functional Magnetic Resonance Imaging (fMRI).

Through the above introduction, we have learned that neuroaesthetics has made great progress in the past. Therefore, the purpose of this study is to make a comprehensive and quantitative review and analysis of neuroaesthetics from 1991 to 2018.

Methods

In order to detect the emerging trends of neuroaesthetics, we use Web of Science Core Collection and CiteSpace to complete the bibliometric procedures.

Bibliometric methods refer to a cross-disciplinary science that uses mathematical and statistical methods to analyze quantitatively all knowledge carriers. It is a comprehensive knowledge system that integrates mathematics, statistics to quantification (Yu, Davis, & Dijkema, 2014, pp. 280-293]. Through quantitative analysis, the answer which describes trends of academic publications and their citation counts can be provided by bibliometric methods which will help us to map the general view of the specific works and evaluate the productive authors within the field and the performances of the journals.

Data Collection

The bibliographic database of neuroaesthetics would be created via two steps.

First, choose 1991-2018 as the time node. At the time of writing, due to the late birth of neuroaesthetics, this time node setting can facilitate the full observation of the development path of neuroaesthetics from birth to the present. Full record and cited references from all articles and reviews published in neuroaesthetics journals between 1991 and 2018 were exported as text files from Web of Science Core Collection. Therefore, a large number of corresponding references can be used.

Second, the data resource is Web of Science Core Collection, because it provides more information about the reference (Chen, Dubin, & Kim, 2014, pp. 1295-1317). We used the literatures exported from Web of Science Core Collection to set up our data files. Our research shows that the data of Web of Science Core Collection in the field of neuroaesthetics are the most standard and effective. Using the literatures from Web of Science Core Collection was to make sure we could know the frontier conclusions came from the key authors, and grasp useful data over years to observe the historical change of the development of neuroaesthetics. And we used the keyword “neuroaesthetics” to search the literatures. The information we choose to export literatures includes author data, keywords, citation data, and abstract. We sorted the number of publications in the appropriate order by author, country, institution, and journal names. At the same time, the relevant literatures were reviewed before sorting, and then the co-author network and the common citation network in the field of neuroaesthetics were determined based on the sorted results. This result reveals the relevant research fields of neuroaesthetics and will also reveal the future interdisciplinary direction in the field of neuroaesthetics.

In addition, in sorting out the data, we found that there may be different forms of references to an article. Therefore, we translated the reference form into the standard form of the same digital object identifier (doi).

CiteSpace

We used CiteSpace to analyze bibliometric data and to visualize the data network, which will reflect the dynamic changes in neuroaesthetics.

Firstly, we imported data from Web of Science Core Collection into CiteSpace. CiteSpace is a software for visual analysis of documents. Using CiteSpace, we can complete cocitation analysis by selecting items, such as literature data. In order to analyze the relevant literatures, we searched relevant literatures in Web of Science Core Collection. We imported the data from Web of Science Core Collection into a plain text, sent the text to the new created project named “neuroaesthetics” in the CiteSpace. After the data were imported into CiteSpace, the network of neuroaesthetics core literatures was visually analyzed. In addition to showing the network of core literatures in the graph from a visual perspective, the size of the nodes in the graph is used to indicate the degree of centrality, and the width of the link indicates the strength of the relationship between the nodes. The thicker the links are, the higher the relevance of their research is.

Secondly, we used the same method to analyze keyword co-occurrence and author network. Therefore, closer links between the two authors indicate that the authors have more in common in their research interests and cooperate more frequently. In addition, for visualizing keywords, the larger the font of the label is, the more frequently the keyword appears (Halvey & Keane, 2007). However, for some related variable analysis, due to too many links, it is impossible to directly understand the visualization process. Thus, we made the cluster.

Co-cited References Analysis

A co-citation network with a “time slice” overlay will be also used to reflect the dynamic changes in neuroaesthetics research fields (Chen et al., 2014, pp. 1295-1317). We extracted some landmark references through co-cited references analysis, which can describe some hot topics and representative authors in this area. In this study, the time periods are one year for the topics neuroaesthetics and the top 50 results are selected.

Dual-Map Overlay Analysis

We also did the dual-map overlay analysis which was developed and embedded into CiteSpace by Chen and Leydesdorff (2014, pp. 334-351). The dual-map overlays can identify the dynamics of previous study on the basis of the data set with cross-disciplines. It is necessary to do the dual-map overlay analysis for grasping the characteristics in this study.

Burst Detection Analysis

The function of burst detection searches for scientific features that have high intensities over limited temporal durations and capture the sharp increases in interest in a specific research field (Li & Chen, 2017). Burst detection can present some topics which were actively discussed in neuroaesthetics for a time. The analysis of burst detection can find the emerging trends in the area of neuroaesthetics.

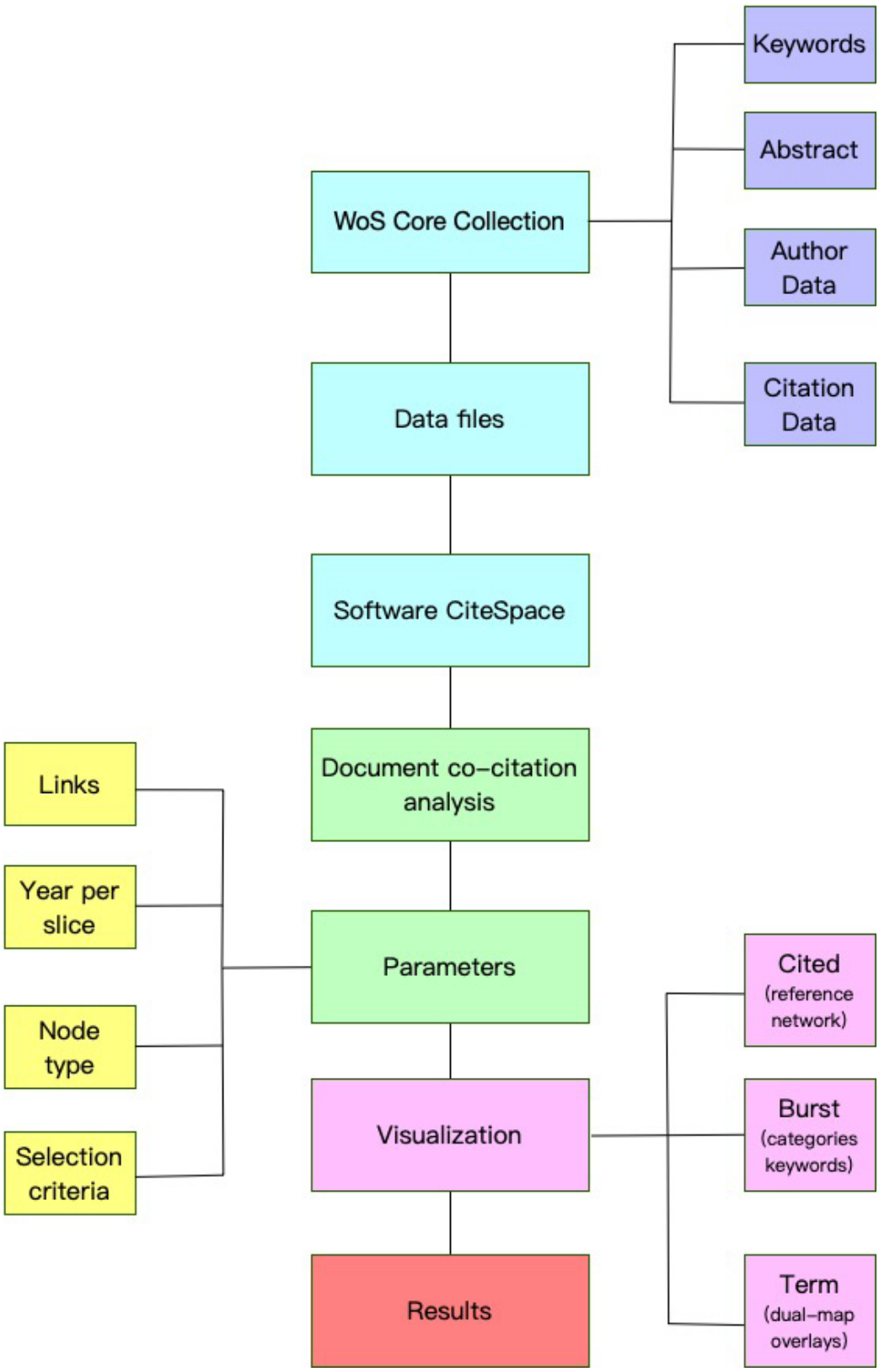

Figure 1. Mind mapping.

Research Theme

Through the above data collation and analysis, it is actually been evolved that this article is about the emerging research field of neuroaesthetics, and we want to know the possible research directions and development trends of this field in the future through the analysis. Therefore, this article aims to analyze neuroaesthetics quantitatively and trace its evolution from 1991 to 2018 by analyzing Web of Science Core Collection which is 144 articles in total.

Results

Landmark Articles of Co-cited References

Figure 2 shows the citation patterns with citation tree-rings across multiple time slices. For the topic "neuroaesthetics", we extracted 144 references; the most cited of the top 16 documents were cited more than 15 times, of which Chaterjee published the most cited articles in 2011, 46 times. According to these references, the research progress and development direction of neuroaesthetics can be fully understood.

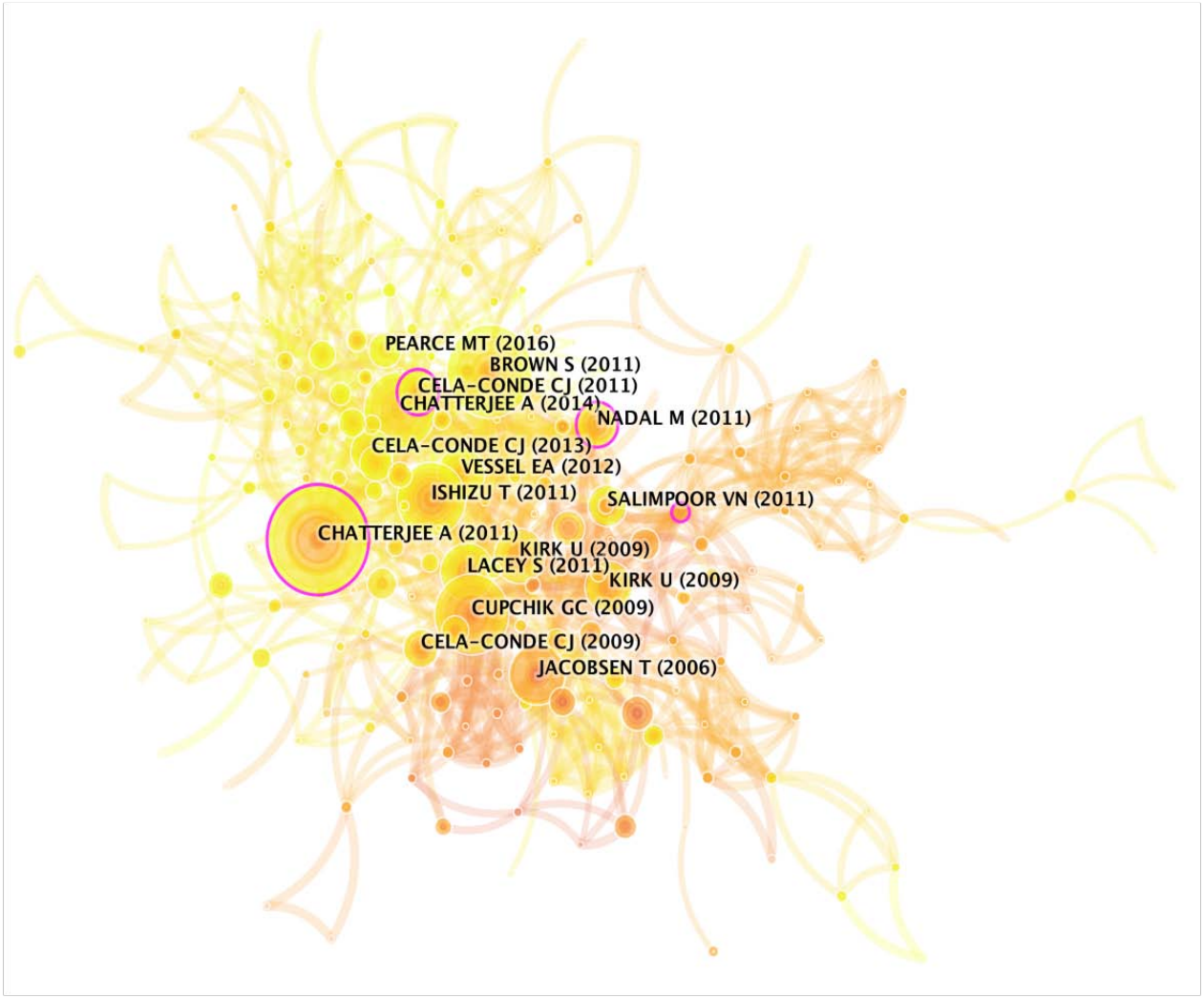

Figure 2. Cited reference topic neuroaesthetics (Modularity Q: 0.6411Mean Silhouette: 0.2725).

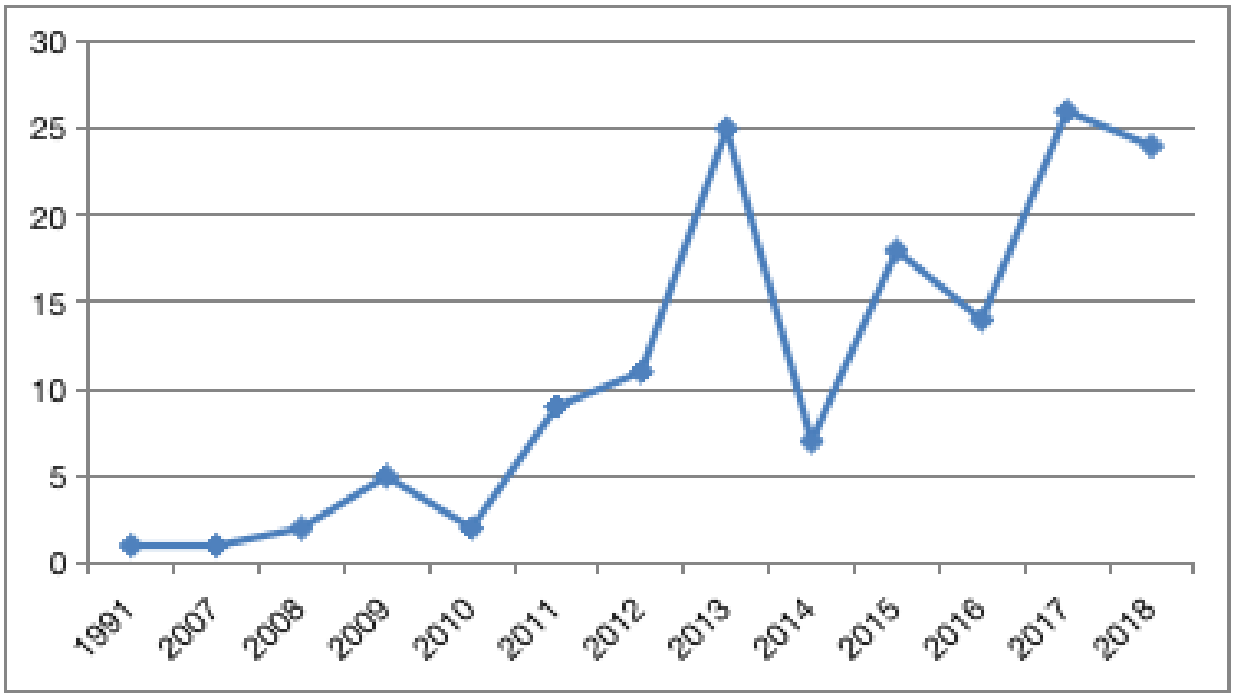

Figure 3. Articles on the Web of Science Core Collection 1991-2018.

And as shown in Figure 3, since the 1990s, neuroscience began to experiment with interdisciplinary and multivariate development; articles on neuroaesthetics began to appear gradually. Due to the concept of neuroaesthetics proposed by Zeki et al. in 1994, articles on neuroaesthetics began to appear gradually. In the early 20th century, under the influence of Zeki, many specialized neuroaesthetics institutions began to be established, the number of articles published in neuroaesthetics began to enter the first peak. Zeki (1999) firmly believed that the study of neuroaesthetics has an indispensable and unique contribution to the perfection of human aesthetics theory. The early studies mainly focused on the aesthetics of visual art. This is not only because of the visual art of intuition and representativeness, but also because our current understanding of the visual nervous system is the most systematic and comprehensive.

Since the 21th century, Chatterjee (2003), as a representative of promoting neuroaesthetics, had further explored neuroaesthetics based on the concept of predecessors. Chatterjee, Thomas, Smith, and Aguirre (2009, pp. 135-143) first explored the neural response that people produce when faced with faces with different appeals in 2009. In the article, Chatterjee pointed out that for those attractive faces, both adults and children with the same cultural background and cross-cultural background, there is a high degree of consistency in judgment, which indicates that there are universal principles of beauty waiting for us to discover and explore. Thus, the disposition to engage attractive faces is present in brains; some components of the disposition are likely to be universal, components that may have distinct neural underpinnings. The results of this study by Chatterjee et al. (2009) confirmed that the understanding of facial beauty is related to an identifiable neural response. Chatterjee also pointed out understanding of symmetry and grouping for this region can affect aesthetic judgment.

Then, in 2011, Chatterjee portrayed the current state of neuroaesthetics pointed out the challenges that neuroaesthetics as an emerging field and the future worth pursuing. In the article, Chatterjee introduces

Livingstone's view of neuroaesthetics into the introduction of neuroaesthetics who believes that there are similarities in neuroaesthetics, between how artists combine colors to evoke people's aesthetic responses, how specific aesthetic effects, and how the nervous system understands and organizes its visual world. And Chatterjee divided aesthetics into three main aspects: First part is the aspect of perception—aesthetic perception can distinguish between form and content (Woods, 1991, pp. 105-114; Russell & George, 1990, pp. 15-30). The remaining two aspects are the aesthetic activities, the emotional response to the appreciation of the landscape, and the aesthetic judgment which are the same hierarchical organization as the most complex biological systems.

After that, Kirk, Skov, Christensen, and Nygaard (2009, pp. 306-315), Chatterjee (2002; 2011; 2014; 2015), Chatterjee and Vartanian (2014, pp. 370-375), and other scientists entered the second stage and began to study in the field of neuroaesthetics officially, that is, to explore how to establish an explanatory framework for the regulation mechanism of brain nerves during human aesthetic activities, and to understand humans from the perspective of neuroscience. Under the leadership of a group of scientists, such as Chatterjee and Kirk, the number of articles published in neuroaesthetics began to enter the second peak in 2013. And because the research theme is gradually clear, it is no longer as early as the article, the articles are scattered in various categories, the core journal publishing categories are gradually fixed in neuroscience and psychology, and the number of articles published in core journals is gradually stable in 20-25 articles. With the emergence of the field of neuroaesthetics, the division of research areas has become a problem. Because neuroaesthetics is an interdisciplinary field that combines different academic backgrounds and research interests of scientists, it needs to be understood at several different levels. Just as the corresponding explanation of the neuroscience theory proposed by Nadal (2013, pp. 135-158), that neuroscience should not be only understood at the technical and implementation level, but also from the perspective of natural science, and should also focus on other relevant factors that may change. Otherwise, it will also lead to the results that we cannot enough to fully understand aesthetics. Therefore, if we want to study the field of neuroaesthetics, we must focus on the study of philosophical aesthetics, art theory, neurological aesthetics, psychological aesthetics, and evolutionary aesthetics, to explore neuroscience and aesthetics at a deeper level.

As the information can be seen from in the article, most of the articles in the field of neuroaesthetics are based on the actual neuroscience experiments, using fMRI and other experimental methods to draw relevant conclusions. Kirk and Chatterjee (2013), as mentioned above, used fMRI to explore the neural response of human aesthetic activities. Obviously, with the development of neuroscience, the innovation of scientific and technological means and experimental methods, such as fMRI have become an indispensable and important foundation to help construct the theoretical framework of neuroaesthetics. As an experimental method commonly used in neuroscience, fMRI is often used in neuroaesthetics experiments. In addition to the representative Chatterjee experiment in the previous section, Kirk et al. also used the fMRI method in 2009 to explore whether the differences in aesthetic evaluations of art related knowledge can be detected as differences in neural activity (Kirk et al., 2009, pp. 306-315). The experimental results of Kirk et al. (2009, pp. 306-315) demonstrated that professional knowledge adjusts the brain region to aesthetic processing or cognitive type, regardless of the aesthetic rating, and also shows that in the aesthetic judgment, the stimulus value of the medial orbitofrontal cortex (OFC) and the bilateral sputum is subject to professional knowledge. In contrast to OFC, the voxels in the ascospore fraction of the anterior cingulate gyrus are contrary to the expert's high and low response compared to non-experts. In addition, Kirk et al. also observed that the response of the hippocampus

and the forequarters on both sides proved that the expert and non-experts had different neural responses to the professional stimulus itself, regardless of the aesthetic rating. This shows that experts can integrate current input into the framework of prior knowledge and use this information to organize aesthetic judgments.

It is undeniable that 2004 is a landmark year for significant progress in neuroaesthetics. Some researchers began to use normal human to perform non-invasive neuroimaging techniques. The research work they published in this year differed in experimental design, technology, stimulating materials, and subjects, and the results obtained were not the same, although their research objectives were similar with each other. Their goals were to find relevant neuroanatomical parts of the subject's aesthetic preference. And the results of Zeki's was the inner sacral frontal cortex (mOFC), the anterior cingulate gyrus, and the left parietal cortex are more active, for the beauty stimulation; for ugly stimulation, the motor cortex is more active. The results of Cela-Conde et al. were the dorsolateral prefrontal cortex (DLPFC) activity is stronger for the stimulation of the genital. And the results of Vartanian were that the activity of the right caudate nucleus decreased with the decrease of preference; the activity of the left cingulate gyrus and bilateral occipital cortex increased with the increase of preference. The above results are not contradictory and can be complemented by each other for further analysis by the researcher to understand the neural basis of art appreciation and aesthetics.

Emerging Trends and New Developments (1999-2017)

Subject categories with citation burst. Figure 4 shows that the burst of subjects for the data set on the "neuroaesthetics" topic obtained from Web of Sciences Core Collection. The analysis results show that the value of Modularity Q is 0.3781 and the value of Mean Silhouette is 0.7898. From the focus of applied research over the past 20 years, we find that, first of all, publications are mainly derived from these subjects: psychology, neuroscience, and neurology, indicating that neuroaesthetics is an important branch of neuroscience. At the same time, we cannot ignore that behind these subjects is the continuous development of technology, which has made neuroscience and neuroaesthetics made rapid progress in these 20 years. In short, all of these topics are at the level of neuroscience. In other words, current neuroaesthetics are mainly concentrated in the field of neuroscience.

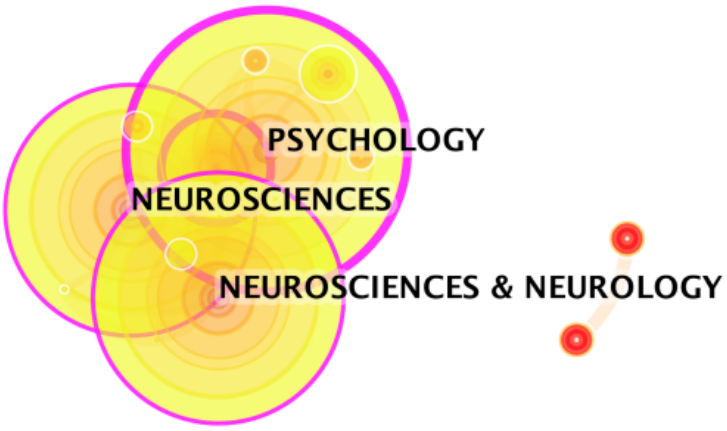

Figure 4. Burst subjects analysis of topic neuroaesthetics (Modularity Q: 0.3781Mean Silhouette: 0.7898).

Keywords with citation burst. Figure 5 shows the cluster of neuroaesthetics studies in Web of Science Core Collection revealed by analysis of burst keywords. The analysis results show that the value of Modularity

Q is 0.4182 and the value of Mean Silhouette is 0.5026. The network community structure is significant, and the clustering result is reasonable. It can clearly reflect the research trend of neuroaesthetics. The research cluster is relatively concentrated. The early research of neuroaesthetics combined the ideas of aesthetics and brain emotion perception.

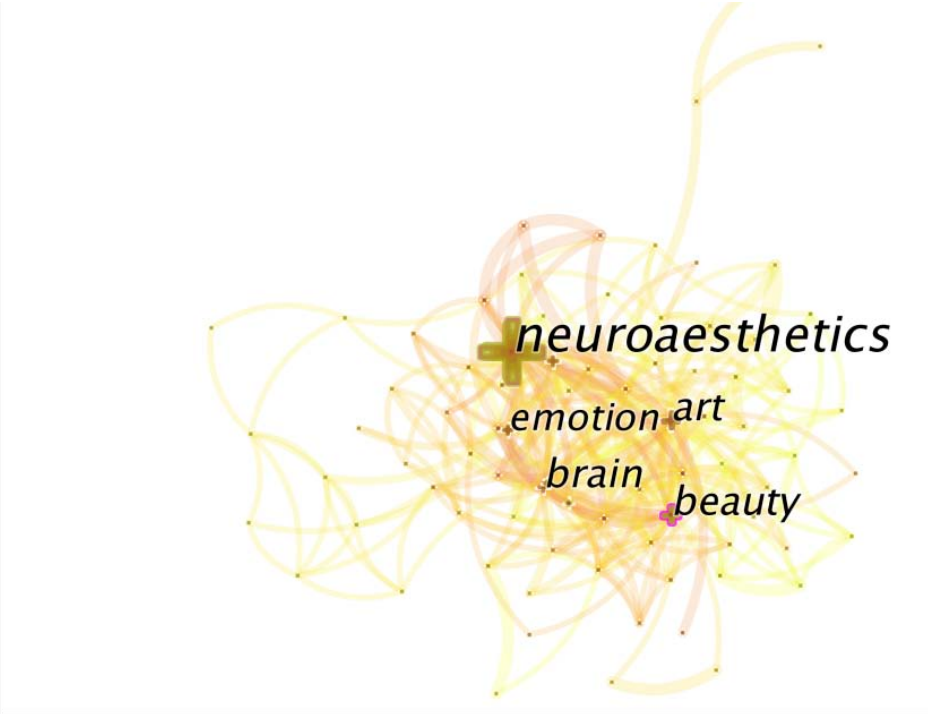

Figure 5. Burst keywords analysis of topic neuroaesthetics (Modularity Q: 0.4182Mean Silhouette: 0.5026).

As shown in Figure 5, with the advent of neuroaesthetics, after 2009, attention to aesthetics and art exploded in the field of neuroscience. In these departments, when the neuroaesthetics did not rise, these relevant researches in the field of neuroscience were in weak positions. The outbreaks of the keywords “aesthetics”, “art”, and “emotion” in 2009 and 2011 also set off the field of neuroaesthetics which explores how the human brain conducts artistic expression and emotional expression. With the gradual development of the discipline, people began to pay attention to the neural regions applied by aesthetic judgment, and applied the conclusions to the field of art, such as music and dance. Calvo-Merino, Jola, Glaser, and Haggard (2008, pp. 911-922) proposed a neuroscience-related study on the response of human aesthetic perception activities to performing arts. After studying the human brain region, Calvo-Merino et al. also found that human activities during the dance stimulation period were related to subsequent independent aesthetic evaluations of the same stimulus. At the same time, the experimental results also indicate that the visual and sensorimotor brain regions may play a role in the automatic aesthetic response of dance, and therefore dance performance is widely recognized by the public.

Interdisciplinary Level With Dual-Map Overlays

As shown in Figure 10, a new interdisciplinary discipline emerged.

The economics & political discipline and the psychology, education & social discipline, and four groups of transdisciplinary citation patterns were observed. The Earth, geology & geophysics discipline combined with

the ecology, Earth & marine discipline, the molecular, biology & genetics discipline combined with the medicine, medical & clinical discipline, the health, nursing & medicine discipline combined with the medicine, medical & clinical discipline, and it also combined with the psychology, education & social discipline.

The last four groups could reflect a paradigm shift for neuroaesthetics. And we could tell through absorbing the theories of the molecular, biology & genetics discipline and the health, nursing & medicine discipline, the medicine, and medical & clinical discipline was reinforced. We also found that the health, nursing & medicine discipline provided a basis for the development of the medicine, medical & clinical discipline and the psychology, and education & social discipline.

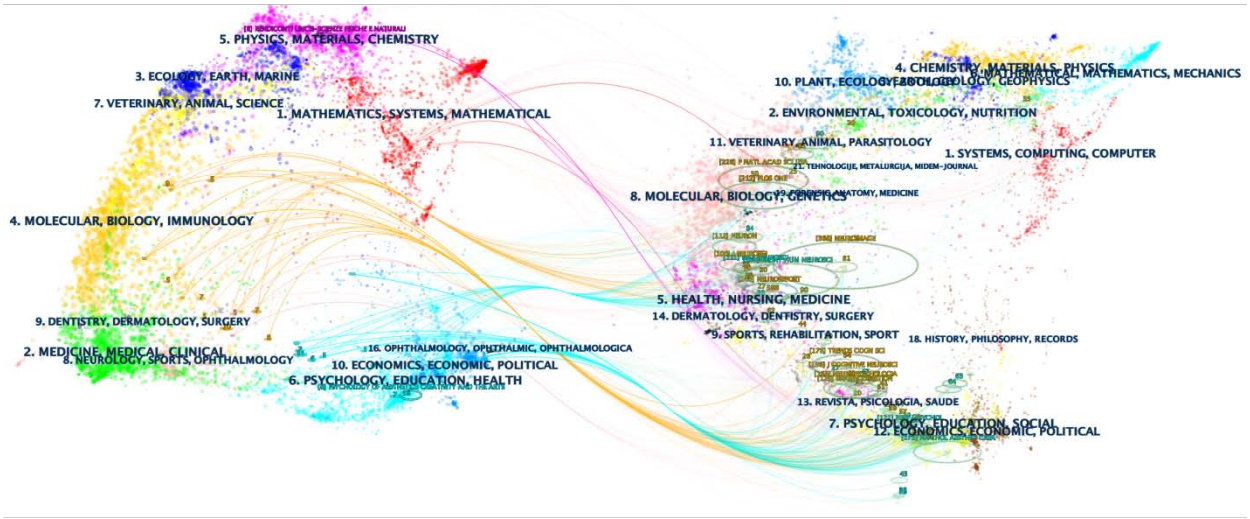

Figure 6. Dual-map analysis of topic neuroaesthetics.

Empirical Characteristics of Publications

Figures 7 and 8 are visual analysis of countries and institutions. The results of visualization in Figure 7 show that the value of Modularity Q is 0.3075 and the value of Mean Silhouette is 0.5531. The network community structure is significant and the clustering results are reasonable. The results in Figure 8 show that the value of Modularity Q is 0.72 and the value of Mean Silhouette is 0.7143. The clustering results obtained by the network are significant, and the clustering results are highly reliable, which can accurately reflect the main distribution of current neurological aesthetics. Neuroaesthetics is still dominated by European and American countries, mainly in United Kingdom, Germany, United States, Canada, and other countries. Asian countries began to develop after 2010s, and Asian countries are dominated by East Asian countries. The reason why the relevant academic institutions in Europe and United States in Figures 7 and 8 become the research subject is precisely because of the visual analysis of the core author in Figure 9.

Figure 7. Analysis of country (Modularity Q: 0.3075 Mean Silhouette: 0.5531).

Figure 8. Analysis of institution (Modularity Q: 0.72; Mean Silhouette: 0.7143).

The reason for the emergence of European and American countries is the early academic influence of Zeki on neuroaesthetics. In 2005, Zeki Institute of Neuroaesthetics was established in Italy. In 2008, The Association of Neuroesthetics was established in Berlin, Germany. And "the aesthetic cognitive approach" has become one of the main topics of the International Conference on Empirical Aesthetics. The Neuroaesthetic Research Center centered on Zeki and University College London radiates the entire European region and forms a research trend in neuroaesthetics. Compared with the influence of Zeki in European countries, although the ideological methods are the same, the research fields and interests of neuroaesthetics in the United States and Canada are more diverse. And their subject background is mainly in the field of psychology and neurology.

Now, the new generation of representative scholars are Chatterjee (2003), Chatterjee et al. (2009, pp. 135-143), Jacobsen (2018, pp. 27-42), and Jacobsen, Schubotz, Höfel, and Cramon (2006, pp. 276-285). They mainly use the latest technology of neuroscience and the latest achievements to seek experimental explanations

for aesthetic phenomena. Under the guidance of neuroscience, they explore the aesthetic issues from multiple angles. After nearly 20 years of development, neuroaesthetics has formed a clear research field. Based on the research methods of cognitive neuroscience, it has achieved a series of aesthetic research results in visual and auditory art, and will usher in cognitive science and the prosperous period of aesthetic development.

Figure 9. Analysis of author (Modularity Q: 0.375Mean Silhouette: 0.4918).

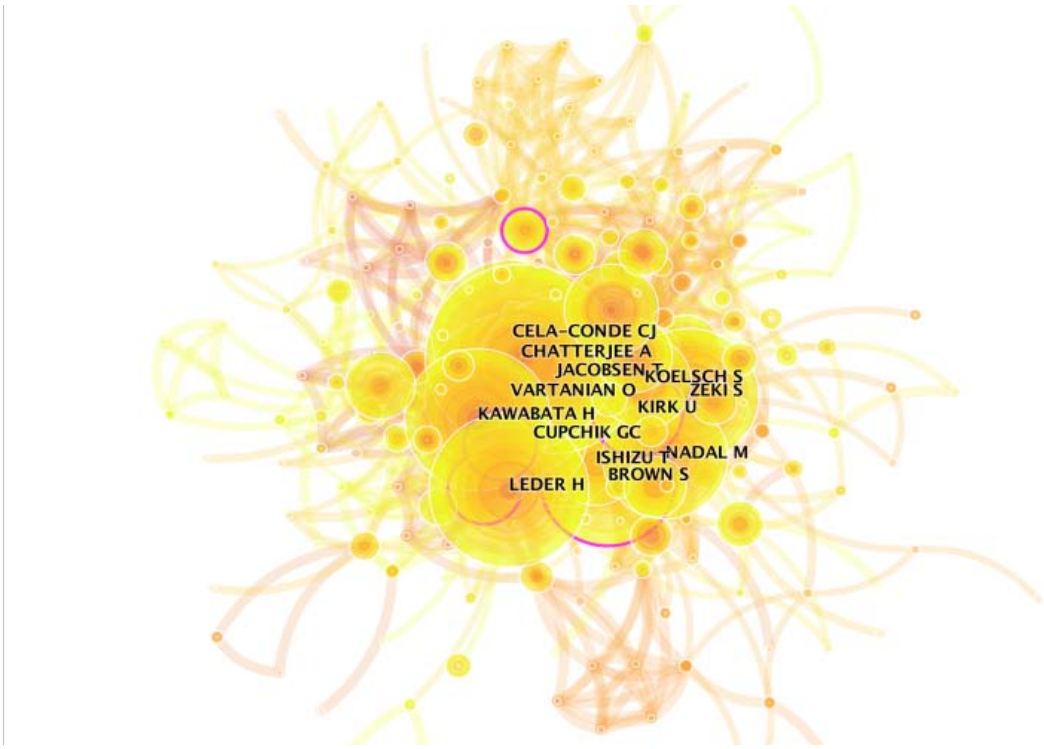

Figure 10. Analysis of cited author (Modularity Q: 0.5065Mean Silhouette: 0.2709).

Figures 9 and 10 are visual analysis of authors and cited authors. The results of visualization in Figure 9 show that the value of Modularity Q is 0.375 and the value of Mean Silhouette is 0.4918. The network community structure is significant and the clustering results are reasonable. The value of Modularity Q is 0.5065 and the value of Mean Silhouette is 0.2709. It can also be seen from the reference analysis in Figure 2 and the visual analysis of the cited authors in Figure 10. Cela-Conde, Kirk, and Chatterjee have many articles

been cited many times; Chatterjee, Vartanian, Jacobsen, and Leader are the most cited authors. As in the previous analysis of the institutions and countries, it is these authors who are in different academic institutions in Europe and the United States that have improved the research level of their academic institutions in this field, which in turn has led more scholars in the country to participate in the emerging field of neuroaesthetics. It is under the leadership of these authors that contemporary, especially the co-authors of the core authors of Cela-Conde, Kirk, Leader, Jacobsen, and Chatterjee have greatly promoted the further development of neuroaesthetics in European and American countries.

In addition, Asian countries, such as China and Japan began to understand neuroaesthetics in the late 2010s (Zhang, S. Y. Lai, He, Zhao, & S. X. Lai, 2016, pp. 229-238; Osaka, Minamoto, Yaoi, & Osaka, 2012, pp. 26-29; Yeh, Lin, Hsu, Kuo, & Chan, 2015, pp. 151-160). However, it needs to be recognized that there is no the leading core authors like Chatterjee in Asian countries, neuroaesthetics in Asia are still in their infancy, the number of published articles is still far less than that of European and American countries, and the research topics are scattered. Asia countries always maintain a research gap of three to five years with European and American countries. For example, Zhang and Lai and others focus on the aesthetic stimulation brought by hieroglyphics, while observing and analyzing the neural activity generated by different regions of the brain caused by this aesthetic stimulation (Zhang et al., 2016, pp. 229-238); Osaka et al. (2012, pp. 26-29) analyzed the response of the brain amygdala to sad facial emotions. For the aesthetics process of observing art works, Yeh et al. (2015, pp. 151-160) analyzed human aesthetic judgments and separates neutral mechanisms of aesthetic emotions.

It is undeniable that Asian countries' attention to the emerging field of neuroaesthetics provides scholars with sufficient cases and new inspiration. However, it is still necessary to strengthen the research process of neuroaesthetics in Asia. The neuroaesthetics research in Europe and the United States has formed a certain academic scale, but neuroaesthetics still has a lot of room for development as a new subject. At present, there is no general concern or research on neuroaesthetics in Asia. Therefore, if Asian neuroscientists get together with psychologists to explore neuroaesthetics in the future, the research topics will be expanded and deepened, which will solve the bottleneck problem of the current development of neuroaesthetics, and play a breakthrough role in the innovation and development of aesthetics and even world aesthetics, such as comparing the neural mechanisms of Chinese and Western aesthetics, whether the aesthetics of different cultural backgrounds have a common basis for the aesthetic neural mechanisms of different cultural aesthetic materials.

Discussion

As an interdisciplinary subject that attempts to understand aesthetics from the new perspective of positivism, the emergence of a new discipline of neuroaesthetics provides further development not only for aesthetic research, but also for the possibility of further development in other disciplines. In order to explore the future trend of the development of the emerging field, neuroaesthetics, this study used bibliometric methods and CiteSpace to do visual analysis, analyze the changes in the field of neuroaesthetics in the past 27 years.

First, with the increase of people's interest in the emerging field of neuroaesthetics, the number of related articles published in core journals has increased significantly, and has gradually stabilized over 25 in the past five years. And as time flows, with the development of neuroaesthetics, people understood the neuroaesthetics from the initial stage, and then delineated the field. Until now, the research theme had gradually extended to the emotions of human aesthetic activities. Scientists are trying to construct the theory of the analysis results, and

try to apply the theory to the life. The physical responsiveness of people watching art works involves not only the imitation of what they see in the work or the actions they suggest, but also the emotional response to the work. Neuroanatomical studies have found that there is a neural connection between F5 and PF (BA 7b) and PF and superior temporal sulcus (STS), while STS is part of the emotional processing neural circuit that contains the amygdala and the frontal cortex. Other studies have shown that when people observe the information expressed by body movements, the brain amygdale, and supraorbital sulcus are activated. These findings provide partial evidence for the mechanisms that mimic the experience of empathy.

Next, the analysis of the core literature and the study area shows that Nadal, Leader, and Chatterjee are the main author clusters, which also greatly promoted neuroaesthetics in Europe and America. The research and understanding of the field, and through the research themes of the article, we can find that the development trend of neuroaesthetics is moving from the early analysis of phenomena to the current attempt to construct a relatively reasonable corresponding mechanism. For example, Chatterjee's 2014 concept of neuroaesthetics and the reorganization of the meaning of the subject (Pearce et al., 2016, pp. 265-279), the re-division of the field of neuroaesthetics from the perspective of the humanities, and the redefinition of its subject value.

Finally, using bibliometric analysis and CiteSpace, these methods and tools provide an overview of neuroaesthetics and help us understand them, so we believe this analysis will also help researchers research related articles and topics.

However, this study still has limitations. We searched the term "neuroaesthetics" to identify and extract source articles, which might miss out articles that did not use this keyword. In addition, the literature was extracted only in the Web of Science Core Collection database and did not cover all sources. Therefore, further work can be carried out to develop more sources for further comparison of results.

As a new subject, neuroaesthetics also faces many challenges and difficulties. First, the experiment of neuroaesthetics is realized by the method of neuroimaging, but whether the method of neuroimaging can truly record the related neural activities of human aesthetic experience. Experiments generally quantify the stimuli response of the subjects, but the effectiveness of this strategy can be quantified by meaningful quantification based on aesthetic experience. However, to what extent can this quantitative grading be able to properly characterize people's aesthetic experience and reflect the essence of people's aesthetic experience?

The second is the issue of the scope of the subject of neuroaesthetics. Neuroaesthetics should simply summarize its research into the aesthetic experience of human beings, focusing on aesthetic issues. Or we should also believe that neuroaesthetics can clarify the creative activities of art, focus on the field of art, and generalize the artistic experience to the neurobiological mechanism, and believe that it should not be narrowly focused on the aesthetic response and eventually tear apart the broad picture of art.

In addition, the study of neuroaesthetics is mainly limited to visual art, auditory art, and other art fields, such as action art, literature is relatively rare. In addition to exploring the neural mechanisms of different art fields, neuroaesthetics should also studies whether the aesthetic activities in different art fields have the same neural mechanism to locate specific brain regions related to aesthetics in the brain and to subdivide them into functions, in order to further understand the neural mechanism of the occurrence of aesthetic activities. Thus, although we have discovered some new hot topics in neuroaesthetics and the meaning of these topics needs further analysis, we still need further understanding of neuroaesthetics. With the development of the emerging field of neuroaesthetics, we hope that the field will become more diverse, and the theory will be more perfect and become a hot field.

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