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Mapping and clustering analysis on neuroscience literature in Turkey: a bibliometric analysis from 2000 to 2017

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Abstract
This study is aim to determine significant changes and trends in neuroscience literature concerning Medical Subject Headings (MeSH) from 2000 to 2017. This article encourage researchers to help identify perhaps the most influential studies and combine detailed evidence into study-considered higher education. To our knowledge and understanding, almost no study found alterations in neuroscientific literature during the last decade in Turkey. In this study, the main aim is to present a science map of "Neuroscience literature", is a growing field of research in Turkey. This study explores maps of scientific publications related to research in Neuroscience that accuracy of clustering and classification of scientific fields is enhanced by incorporation of algorithms and main bibliometric analysis. Data were extracted from the Web of Science (WoS) database and matched with PubMed database via PubMed ID. Only articles published in journals classified under the Web of science category (WC) "Neurosciences" over the period of interest were included. MeSH term, abstract fields and references of each included publication were extracted and analyzed via Bibliotools software to identify recurring terms with high relative citation scores. MeSH term maps were produced for publications over the study period to illustrate the extent of co-occurrence, and the impact of terms was evaluated based on their relative citation scores. To further describe the recent research priority or "hot spots," MeSH terms, Journals, authors with the highest relative citation scores were identified annually. We focused on two successive periods: in 2000–2007 there are 1807 publications in WoS and 1510 publications in the bibliographic coupling (BC). 1291 publications gathered in 16 top clusters and 1103 publications gathered in 47 subtop clusters. In 2008–2017: there are 3668 publications in WoS, 3312 publications in the BC network. 2924 publications gathered in 20 top clusters and 2500 publications gathered in 87 subtop clusters. In the corpus description interface, interactive tools are used to explore the nature of the two studied corpora by listing MeSH terms, references, categories, authors, journals, institutions, countries, etc. by frequency of use. In the BC interface, interactive tools are used to explore the multiple dimensions of the topics (or clusters) unveiled by our analysis. The two periods were studied independently, and although we use matching colors for topics that obviously correspond to one another from one-time period to another. We focused on two successive periods: in 2000–2007 there are 1807 publications in WoS and 1510 publications in the bibliographic coupling (BC). 1291 publications gathered in 16 top clusters and 1103 publications gathered in 47 subtop clusters. In 2008–2017: there are 3668 publications in WoS, 3312 publications in the BC network. 2924 publications gathered in 20 top clusters and 2500 publications gathered in 87 subtop clusters. In the corpus description interface, interactive tools are used to explore the nature of the two studied corpora by listing MeSH

terms, references, categories, authors, journals, institutions, countries, etc. by frequency of use. In the BC interface, interactive tools are used to explore the multiple dimensions of the topics (or clusters) unveiled by our analysis. The two periods were studied independently, and although we use matching colors for topics that obviously correspond to one another from one-time period to another. In recent years, because of an increase in the size of the aging population, the trend of neuroscience research has been increased. Neuroscience is currently the fastest growing area in basic scientific research. This paper gives a contemporary summary to scientists and medical professionals interested in research and innovation in this field. Furthermore, Neuroscience research plays a vital role in the development of instruments categories of emerging medical technology. It is clear that this paper helps researchers who study the neuroscience to recognize significant changes and trends in the literature of neurosciences.

Keywords Bibliometrics · Neurosciences · Science mapping · Co-occurrence · Bibliographic coupling · Clustering · MeSH terms · Scientometrics

Introduction

This study was carried out to assess the standing of Turkish neuroscience and how this broad research field has evolved in Turkey in recent years. This study illustrates the most detailed analysis of neuroscience research performance who used an elaborate search methodology to classify relevant research articles and credible scientific metrics variables for quantifying performance. We should evaluate and track the changes regarding the landscape of neuroscience research in Turkey, to indicate evolution regarding research directions, health care priorities and prime translational research topics over a defined period. Such information enables Turkish stakeholders to clearly and quickly identify the most influential research works and incorporate the latest evidence into research-informed education.

Bibliometric is the quantitative analysis of documents in scientific communication by means of their bibliographic content (De Bellis 2009). The term was first introduced by Alan Pritchard in a paper published in 1969, where he defined the term as "the application of mathematics and statistical methods to books and other media of communication" (Pritchard 1969, pp. 348–349). Citation analysis and content analysis are commonly used in bibliometrics. While bibliometric methods are most often used in the field of library and information science, bibliometrics have wide applications in other areas. In fact, many research fields use bibliometric methods to explore the impact of their field, assess the impact of a set of researchers, or the impact of a particular paper. Bibliometric methods are increasingly being used by science mapping for quantifying research performance of institutions and researchers. In this work, we use as main bibliometric method a tool based on the 'bibliographic coupling' as defined by Kessler (1963).

Bibliometric studies could provide relevant evaluations and assessments of the social and scientific relevance of a specific discipline or research field of interest (López-Muñoz et al. 2006). There have been numerous bibliometric studies on the performance of neuroscience research outputs in specific countries, including China (Xu et al. 2003), India (Shahabuddin 2013) and Sweden (Glänzel and Schubert 2003). In addition, similar studies have been conducted in relevant research fields such as psychiatry and psychopharmacology (López-Muñoz et al. 2006). However, to our knowledge, There are

very few papers were published overall changes in the landscape of neuroscience literature across the globe over the last decade. One of the studies in this field is global neuroscience and mental health research (Buchan et al. 2016).

Science mapping has evolved into an approach that is not mainly academic research but used for practical purposes. It is so important that, in addition to numerical measures, the resulting visual maps are considered a useful tool for decision—makers to solve the real problems of research planning and development (Boyack and Klavans 2010). In addition, science maps can be easily understood. The application of visualization techniques to bibliometric maps facilitates the development of new depths of understanding into the structure of the network and detects relationships between nodes that are otherwise difficult to analyze. Many software tools for science mapping analysis have become available with the increase in computing power (Cobo et al. 2011).

The neuroscience trend has been increasing, in particular from 1998 to 2002 (Sharifi et al. 2008). Similarly, the assessment of scientific productivity in the nervous system is assessed in India (Bala and Gupta 2010), Italy (Berardelli et al. 2005), China (Xu et al. 2003), Spain (Gomez et al. 1990) and Brazil (Hoppen and de Souza Vanz 2016). In those days, Bala and Gupta stated that there is an urgent need to increase the research in India's neuroscience. In addition to these studies, some bibliometric studies have been done in the past to analyze neuroscience literature in some countries. For example, Braun et al. (1995). He has analyzed bibliometric information and common manuscript in world neuroscience literature. The evaluation of the country's research outputs in neuroscience has been applied from time to time by different researchers in Europe (Mela and Mancardi 2002) Sweden (Glänzel and Schubert 2003) and Cuba (Dorta-Contreras 2007). As a result of my research, we did not see any work in the field of neuroscience in Turkey. In the above-mentioned studies, neuroscience domain has been studied in general. The researchers specialize in certain topics with more research teams in the fields of psychology, psychiatry and occupational health (Hoppen et al. 2016) None of these studies, however, analyzed the research gaps in subheadings of neuroscience or subfields.

The publication set was constructed, in a first stage, retrieving the works that have been assigned to the category (WC) of Neurosciences in the citation indexes of the Web of Science. From these references, their PubMed Identifier was extracted. In a second stage, these records have been located by querying PubMed database. Subsequently identified publications from PubMed were matched with corresponding records in the WoS citation database, enabling advanced scientometric analyses (see Fig. 1). This approach has several advantages over traditional analyses; most importantly, we identified relevant articles according to their subject indexing at the individual publication level. Traditional performance analyses rely on arbitrary journal subject categories for delimiting the topic of interest, which often leads to the inclusion of irrelevant as well as exclusion of relevant papers published in multidisciplinary journals some of them with high impact.

Bibliotools software were used to form scientific term maps to allow for network visualization Using graph-theory, a network is a set of nodes and links. The nodes must be terms which co-ocurred in a bibliographic field of an article, like authors, keywords or addresses. The links between articles are calculated through their common references, this is the called bibliographic coupling (BC) defined by Kessler (1963), and is used as similarity index between two articles (Grauwin and Jensen 2011, p. 945). This kind of analysis has the main advantage over the traditional co-citation analysis in that it also takes into account publications that have not necessarily been cited, particularly those that are more recently published (Grauwin and Jensen 2011). The network obtained can be partitioned

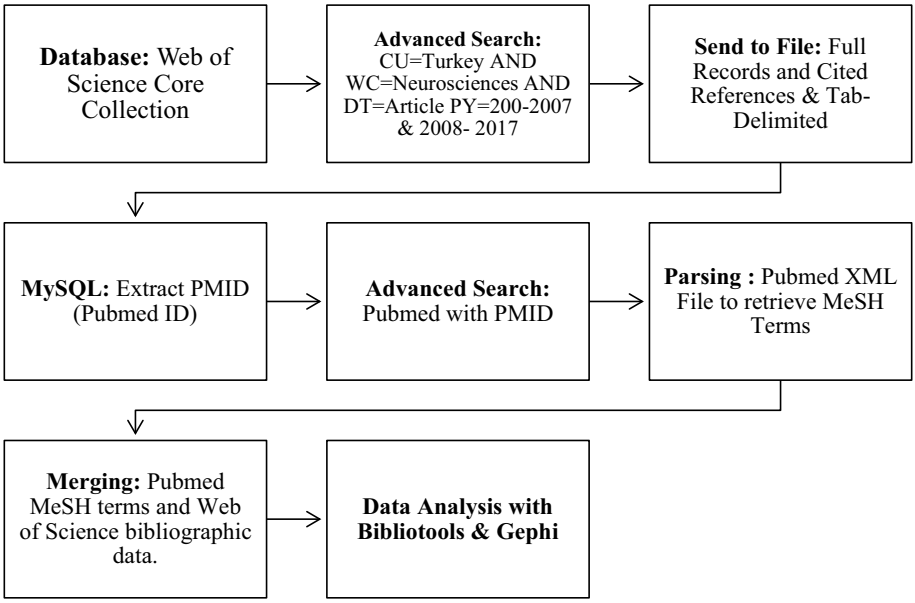

Fig. 1 Data extract and analysis process

into "groups of cohesive articles" or clusters for which the so-called Louvain modularity algorithm is used:

$$\sigma = \sqrt{N}\frac{f - f_0}{\sqrt{f_0(1 - f_0)}}$$

where N is the number of publications within the cluster and f and f_0 are the proportion of publications respectively within the cluster and within the database displaying that item (Grauwin and Jensen 2011, p. 945). In addition, Bibliotools allows analysis based on the co-occurrence (of authors, keywords or addresses) of the source documents, which are also used in this work. The algorithm was designed to ensure that terms that co-occurred more frequently were positioned closer to each other. Terms that occurred more frequently had larger bubbles nodes. Before the final map was created, we visually inspected the map, removed irrelevant terms and combined the abbreviated forms of the noun phrases (Heersmink et al. 2011). For a larger understanding of processes and algorithms included in the Bibliotools application, it can check the following link: http://www.sebastian-grauwin.com/bibliomaps/tutorials.html.

In this study, the main aim is to present a science map of "Neuroscience literature" in Turkey, as part of a growing field of research in the world. This study verifies the additional hypothesis that accuracy of clustering and classification of scientific fields is enhanced by incorporation of algorithms and techniques from text mining and data visualization. In this report, periods from 2000–2007 to 2008–2017 neurosciences data is retrieved from ISI Web of Science and PubMed database. Gephi and Bibliotools, are utilized to analyze the data for generating density maps and density cluster maps of organizations, authors, and journals based on bibliographic coupling and co-citation similarity measures. The

networks and knowledge maps can be depicted differently by choosing different information as the network actor or node, e.g. author, institute or country, keyword, to reflect knowledge structures in micro and macro levels, respectively. Such analyzes can be useful for researchers to do for other countries and then compare them with Neurosciences maps.

Limitations

There really is no article database that covers all articles ever published and that can evaluate all the relationships between them. When we were carrying out our research using the ISI Web of science database, we tried to guarantee wide scope rather than PubMed or Scopus. Common tools such as Web of Science and Scopus provide a particular view of the bibliographic universe because in practice they are the most widely consensus databases in the scientific field and in bibliometric studies that allow analysis based on citations and/or references of publications, with the added advantage of including all institutional addresses of authors, which allows, among other things, studies by country. However, to consider the following limitations. Firstly, mostly publications written in English therefore, missed some significant studies on neuroscience published in Turkish such as.

Secondly, the Web of Science database includes a journal subject classification that is most often used for such purposes, but it is highly problematic for various reasons. Many journals do not have a sufficiently clear subject profile and the spread of topics among individual articles in a journal often go beyond the journal's often somewhat arbitrary subject classification. The subject classification systems include categories called 'multidisciplinary'. These are heterogeneous categories unsuitable for proper analyses. There are other problems, but the main point is that research or subject areas should be constructed based on individual research papers if possible and not the journals they are published in.

There is a third limitation linked to the above. It is not possible to search by subject area in PubMed, because it employs a hierarchical thesaurus for indexing papers that is divided into 16 branches of terms that include, among others, groups of terms related to the anatomical aspects treated in the studies or terms related to the diseases that are involved in them, but there is no subject classification as WoS. Therefore, first of all we are compelled to define Neurosciences as understood by WoS (based on the subject classification of journals). Thus, surely a part of the published Turkish literature on this subject is lost.

Finally, there were still differences between real research conditions and the bibliometric analysis results, since some recently published papers do not have high citation frequency. Lastly, the data in this study are open to expansion, with new studies being published each day, and the increasing trend of publication number might go on for longer than is expected from the proposed model.

Research goal and research questions

This study aims to prepare an interactive and static modular map of Neuroscience literature in Turkey and trace its evolution from periods from 2000–2007 to 2008–2017. For now, the study will also review the research topics about Turkish Neuroscience literature summarized by the special issue and previous research. We have addressed four research questions:

- What are the highly used MeSH terms related with Neuroscience?
- What are the core subject categories (WC) for Neuroscience?
- What is the collaboration network?
- Which are the key Top MeSH terms clusters and what is their sub clusters network group?

To answer these questions, we have used some bibliometrics techniques, a suite of approaches and quantitative methods to analyze the patterns in the scientific literature. Together, these provide a quantitative perspective to objectively classify and analyze neuroscience literature. The overview is augmented by a network analysis of the authors that, together, constitute the neuroscience research community, we have used a set of routines that allows to draw easily different maps of the research carried out. Bibliotools use open source elements to analyze bibliometric data gathered from the Web of Science. We took the literature of Neuroscience in Turkey to show how different maps, using co-occurrence (of authors, keywords, institutions…) and bibliographic coupling can be built.

Methodology

A main challenge in scientometric analyses is to delimit and construct a meaningful subject area to be studied. To do this, it is necessary to obtain a data set that meets this objective.

To obtain our data we save "full records + cited references" and file format "tab-delimited (Win, UTF-8)" of all these articles, the records containing authors, journal, year of publication, title, keywords from the ISI Web of Science database. Our search query is: "CU = Turkey AND WC = Neurosciences AND DT = Article AND PY = 2000–2007 and 2008–2017". As noted above as a third limitation of this study, the reason for using the WC to retrieve Neurosciences literature in Turkey, is that it is not possible to search by subject category in PubMed database. There is no thematic classification of the records in this database. There is a hierarchical classification, the MeSH tree, which uses 16 large branches to describe the indexed articles. Thus, hierarchical thematic sub-trees are used to describe the anatomical parts involved in the studies (A-Anatomy), the organisms studied (B-Organisms), the diseases that are described (C-Diseases) or the drugs that are used in them (D-Chemicals & Drugs). The rest of the hierarchical branches involve: E-Analytical, Diagnostic and Therapeutic Techniques and Equipment, F-Psychiatry and Psychology, G-Phenomena and Processes, H-Disciplines and Occupations, I-Anthropology, Education, Sociology and Social Phenomena, J-Technology, Industry, Agriculture, K-Humanities, L-Information Science, M-Named Groups, N-Health Care, V-Publication Characteristics, and Z-Geographicals. Each record in PubMed is labeled with terms from several of these branches, and it is common for 10–15 terms to be used for their description. The full MeSH tree structure can be found at http://www.nlm.nih.gov/mesh/trees.html.

Once the search has been run, we got a total of 5475 articles on Neurosciences literature in Turkey. Records obtained are parsed and gathered in MySQL tables, which retrieves the handling of the data more straightforward. From those records that have it, we extract the PubMed identifier (PMID). With this list of identifiers, the PubMed database is asked and the XML files containing the MeSH terms are obtained, which are extracted and merged to the MySQL database containing the bibliographic data obtained from the WoS. Finally, the complete data set is analyzed with Bibliotools and visualizing with Gephi. (See Fig. 1).

Finally, a Webpage presenting the BiblioMaps interface based on the analysis of totally 5475 articles on Neuroscience Literature in Turkey:

Please click to reach the publications from 2000 to 2007: http://tr.urapcenter.org/Neuroscience/2000-2007/corpus.html

Please click to reach the publications from 2008 to 2017: http://tr.urapcenter.org/Neuroscience/2008-2017/corpus.html

Contrary to traditional scientometric performance analyses, the present approach is based on a specially constructed publication set that is assumed to broadly cover neuroscience and related research areas in Turkey. The publication set is constructed using MeSH descriptors and subsequently are matched with corresponding records in the WoS citation database. This approach has several advantages over traditional scientometric analysis; most importantly, we identify relevant articles according to their subject indexing at the individual publication level.

Results

Main purpose is to make science mapping easy and rapidly and to show on the example of Neurosciences literatures, what kind of perceptions can be derived from these maps. It should be clear by now that there is not a unique map of a research area, but rather many possible representations, each map covering a projection from a specific perspective. To improve over the limitations of both co-keyword and co-author analysis and gather most of the available information in a variable map, it is possible to include all the co-occurrences between keywords, authors and institutions

Firstly, 2000–2007 Bibliographic Coupling network was built by linking pairs of publications based on the references they share 1510 out of 1807 publications are in the network. The 16 clusters presented here correspond to the ones found in the top-level grouping at least 15 publications. Similarly, it has been built a 2008–2017 Bibliographic Coupling network in this case, 3312 out of 3668 publications are in the network. The 20 clusters presented here correspond to the ones found in the top-level grouping at least 33 publications.

The Neurosciences publication in Turkey before the 21st century were few in number, but since the year 2000, the quantity of articles has increased significantly. Figure 2 shows two periods clearly pointed out by the local regression adjustment that has been carried out. To do this, the 'loess' method implemented in the 'ggplot2' package (Wickham 2016) has been used. The first period, up to 2008, is characterized by a sustained growth in the number of publications. From that year, a second period begins with a greater variability in the data. This is the reason for considering the two periods of analysis mentioned above.

Table 1 presents some context indicators of the publications on Neurosciences in Turkey. The number of authors per paper is around 5 in the first period of analysis, with almost 7 authors per document in recent years. However, in both periods, half of the published papers have 5 or fewer authors (or 5 or more authors, the work with more authors in 2010 is signed by 482 researchers).

The number of institutions that have signed these papers has grown from 2 in the first period to nearly 4 at the end of the second. Logically, the number of citations per document increases as the documents are older, so in 2000 and 2001 they reached an average of 32.6 and 37.5 citations per paper. Half of the papers published in 2017 have at least 1 citation in 2018.

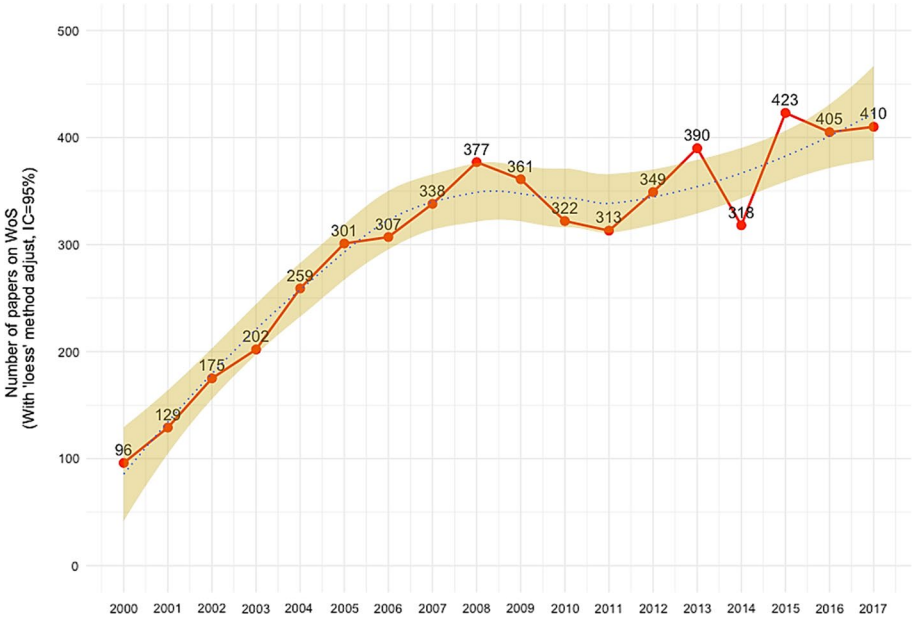

Fig. 2 Number of paper on Neurosciences research area published by year in Turkey, according to Web of Science, from 2000 to 2017

Finally, we conclude with the thematic context using the subject categories in the WoS (WC). In terms of collaboration and multiple allocation criteria, that this database assigns to each indexed journal, we can establish co-occurrence relations by subject. Table 2 shows the 20 subject categories most productive in each period.

As can be seen in Table 2, in the second period there are 8 new subjects that share production with Neurosciences (marked in the graph), on the contrary there are other 7 subjects of the first period that disappear among the most productive. In both periods the multidisciplinary maintains its productive position in three categories (Clinical Neurology, Psychiatry, and Psychology) and improves in another four (Behavioral Sciences, Biochemistry & Molecular Biology, Pharmacology & Pharmacy and Surgery).

The number of citations received in 2018 for published papers is also presented. The number of citations received in 2018 by papers published in both periods is also presented (see Table 2). Given that the number of citations decreases with the time, in each period the data have been normalized including an index in base 100. Some areas become worse with respect to the first period in this base-index, such as Physiology that loses 140 points of impact and Psychology, Experimental with 134 points of loss. In general, the rest of subject categories improve their impact in the field of Neurosciences in Turkey, being the subject of Pathology the one that experienced a greater increase of its impact in almost 231 points, while its production did it on a small scale (from 20 to 28 papers).

Thus, in Turkey, Clinical Neurology, Psychiatry, Endocrinology-Metabolism, Physiology Surgery and Pharmacology-pharmacy, are the most collaborative subject to Neurosciences from 2007 to 2017. Size of the nodes is proportional to the number of times a Subject is used in our database. The width of the links indicates weight between two subjects in the same article. Collaboration between different areas is very important to be reasonable and produce new interdisciplinary knowledge (See Fig. 3).

Table 1 Context indicators of the publications on neurosciences in Turkey

2000–2007						2008–2017					
Year	(a) Authors per paper	Median (a)	(b) Citations per paper	Median (b)	Institutions per paper	Year	(a) Authors per paper	Median (a)	(b) Citations per paper	Median (b)	Institutions per paper
2000	4.8	5	32.6	17.5	2	2008	5.2	5	12.9	7	2.2
2001	4.2	4	37.5	17	2	2009	5.1	5	12.3	6	2.1
2002	4.7	5	25.7	15	1.9	2010	6.6	5	12.5	6	2.6
2003	4.9	5	24.4	13	1.9	2011	5.4	5	10.7	5	2.1
2004	5	5	21.6	11	1.9	2012	5.7	5	9.5	5	2.4
2005	5.1	5	18.6	9	2.1	2013	6.1	5	8.6	4.5	2.6
2006	4.9	5	17.6	10	2	2014	6.4	5	6.9	3	3
2007	5	5	19.7	10	2.1	2015	6.9	5	7	3	3.5
						2016	6.5	5	4	2	3.3
						2017	7.2	5	1.8	1	3.7

Table 2 Neurosciences in Turkey according to most productive subject categories in WoS

Rank	2000–2007 period					Rank	2008–2017 period				
	Subject (WoS category)	Total cites	Total papers	CPP	CPP (Neurosciences = 100		Subject (WoS category)	Total cites	Total papers	CPP	CPP (Neurosciences = 100
1	Neurosciences	40,637	1807	22.5	100.0	1	Neurosciences	30,852	3668	8.4	100.0
2	Clinical neurology	14,400	654	22.0	97.9	2	Clinical neurology	12,774	1264	10.1	120.2
3	Psychiatry	4857	210	23.1	102.8	3	Psychiatry	2477	261	9.5	112.8
4	Endocrinology and metabolism	3751	143	26.2	116.6	4	Pharmacology and pharmacy	1685	136	12.4	147.3
5	Physiology	4986	99	50.4	224.0	5	Surgery	296	128	2.3	27.5
6	Surgery	286	94	3.0	13.5	6	Endocrinology and metabolism	1794	120	15.0	177.7
7	Pharmacology and pharmacy	2151	70	30.7	136.6	7	Biochemistry and molecular biology	1707	114	15.0	178.0
8	Psychology	3103	61	50.9	226.2	8	Psychology	719	100	7.2	85.5
9	Neuroimaging	791	49	16.1	71.8	9	Physiology	1022	99	10.3	122.7
10	Biochemistry and molecular biology	2476	47	52.7	234.3	10	Behavioral sciences	936	81	11.6	137.4
11	Psychology, experimental	2390	41	58.3	259.2	11	Neuroimaging	555	66	8.4	100.0
12	Radiology, nuclear medicine and medical imaging	335	36	9.3	41.4	12	Peripheral vascular disease	423	60	7.1	83.8
13	Psychology, biological	2056	30	68.5	304.7	13	Cell biology	288	55	5.2	62.3
14	Behavioral sciences	1219	29	42.0	186.9	14	Rehabilitation	344	42	8.2	97.4
15	Pathology	363	20	18.2	80.7	15	Computer science, artificial intelligence	562	41	13.7	163.0
16	Anesthesiology	750	17	44.1	196.2	16	Sport sciences	447	39	11.5	136.3
17	Otorhinolaryngology	346	17	20.4	90.5	17	Psychology, experimental	368	35	10.5	125.0

Table 2 (continued)

Rank	2000–2007 period					Rank	2008–2017 period				
	Subject (WoS category)	Total cites	Total papers	CPP	CPP (Neurosciences = 100		Subject (WoS category)	Total cites	Total papers	CPP	CPP (Neurosciences = 100
18	Biochemical research methods	1205	16	75.3	334.9	18	Pathology	734	28	26.2	311.7
19	Audiology and speech language pathology	331	16	20.7	92.0	19	Immunology	302	27	11.2	133.0
20	Developmental biology	272	15	18.1	80.6	20	Mathematical and computational biology	40	22	1.8	21.6

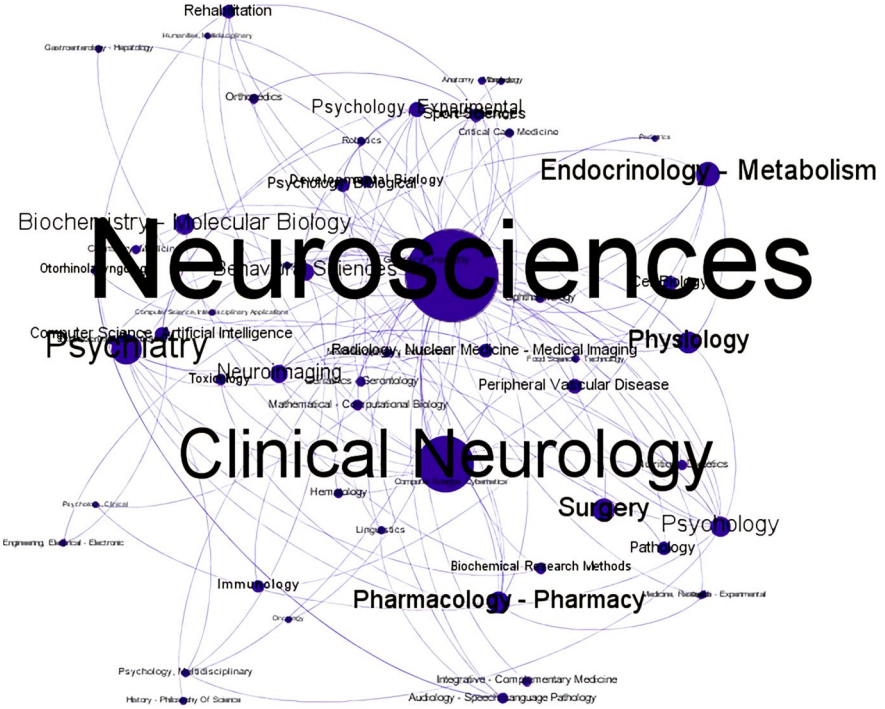

Fig. 3 Neurosciences collaboration network from 2007 to 2017 in Turkey

Next, we will analyze the relationships between the articles based on the co-occurrence of MeSH terms. Table 3 shows the "Top MeSH Terms" of the BC clusters found within the studied database. The BC network was built by linking pairs of publications based on the references they share 5021 out of 5475 publications are in the network. The 27 clusters presented here correspond to the ones found in the top-level grouping at least 10 publications. They gather a total of 4832 publications.

In Table 3, the significance of an item is given by the value of (σ). Bibliographic coupling network was built by linking pairs of publications based on the references. In 2000–2007, there are 16 clusters presented here correspond to the ones found in the top-level grouping at least 16 publications. In 2008–2017, There are 21 main clusters presented here correspond to the ones found in the top-level grouping at least 34 publications. N is the number of publications within the cluster, ⟨Nref⟩ the average number of references per publication. The cohesiveness of the cluster can be measured by: the average degree k of its publications (i.e. average number of links within the cluster per publication), its density in terms of BC links $d = 2k/(N-1)$, the average number of citation per publication (according to Web of Science) ⟨Ncit⟩, the h index h of the cluster (h publications have been cited at least h times).

We analyzed the complete period 2000–2017 (5475 publications) and developed tools to explore the evolution of the whole corpus as well as BC topics (or clusters) during 17 years (see Fig. 4). We focused on two successive periods; in 2000–2007 there are 1807 publications in the Web of Science, there are 1510 publications in the BC network. 1291 publications gathered in 16 clusters and 1103 publications gathered in 47 subtop clusters. From

Table 3 Main clusters of MeSH terms according to 2000–2007 and 2008–2017

2000–2007							2008–2017						
Main clusters	*N*	⟨Nref⟩	*k*	*d*	⟨Ncit⟩	*h*	Main clusters	*N*	⟨Nref⟩	*k*	*d*	⟨Ncit⟩	*h*
Melatonin	206	.50	64.32	0.628	33.19	46	Psychiatric Status Rating Scales	378	38.12	20.44	0.108	8.68	26
Psychiatric Status Rating Scales	153	31.81	30.00	0.395	29.41	39	Rats	363	41.39	37.00	0.204	12.49	32
Animals	148	38.53	12.28	0.167	24.18	35	Epilepsy	247	37.32	12.20	0.099	6.51	19
Migraine disorders	128	26.83	7.30	0.115	22.97	31	Photic stimulation	220	55.65	14.38	0.131	10.56	25
Multiple sclerosis	123	25.73	8.73	0.143	19.45	27	Multiple sclerosis	207	29.01	29.65	0.288	10.91	27
Neuroprotective agents	104	37.10	6.60	0.128	24.42	26	Migraine disorders	200	31.70	15.60	0.157	8.10	20
Evoked potentials	93	44.46	30.67	0.667	49.86	37	Mice	175	35.54	7.66	0.088	10.14	22
Functional Laterality	83	32.30	25.54	0.623	15.71	19	Parkinson disease	168	37.39	25.18	0.302	8.43	21
Cell count	70	37.19	13.66	0.396	23.89	24	Stroke	156	25.79	10.35	0.133	6.49	17
Action potentials	39	29.10	5.79	0.305	9.46	11	Cell count	130	45.87	27.88	0.432	10.57	20
Aged	33	29.91	3.15	0.197	18.06	14	Animals	127	46.45	9.64	0.153	8.91	19
Zinc	28	27.68	4.57	0.339	12.18	12	Muscle contraction	110	31.69	10.29	0.189	5.33	12
Evans blue	27	37.04	4.52	0.348	17.04	13	Blinking	83	30.40	8.10	0.197	5.52	12
Meningioma	22	31.27	2.27	0.216	14.45	13	Amyloid beta-peptides	75	41.11	5.57	0.151	13.16	19
Uridine	18	42.17	7.89	0.928	30.89	14	Carpal tunnel syndrome	64	24.44	9.41	0.299	5.41	11
Molecular structure	16	30.00	3.00	0.400	36.81	12	Mutation	61	29.98	5.64	0.188	18.59	18
							Obstructive sleep apnea syndrome	51	30.20	5.33	0.213	4.31	9
							Medulloblastoma	40	25.48	2.75	0.141	3.30	7
							Ossification, heterotopic	35	25.09	3.77	0.222	8.89	10
							Dizocilpine maleate	34	43.91	6.76	0.410	9.12	10

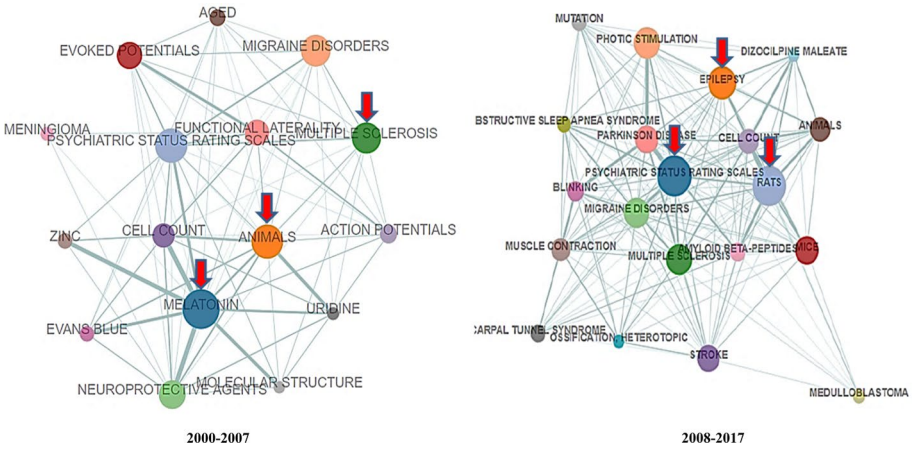

Fig. 4 Network of the most frequently used MeSH terms during 2000–2007 and 2008–2017

2007 to 2018; there are 3668 publications in the Web of Science. There are 3312 publications in the BC network. 2924 publications gathered in 20 clusters and 2500 publications gathered in 87 subtop clusters. In order to find top and subtop MeSH term clusters details to see in Appendix see Table 5.

Size of the nodes is proportional to the number of times a keyword is used in our database. The width of the links indicates weight between two keywords in the same article. We kept only most frequently used 3 top clusters' sub keywords. Colors correspond to a community analysis performed by Bibliotools (see Fig. 4). The focus of resource Neuroscience in during 2000–2007 and 2008–2017 was clustered into 16 topics and 20 topics (see Fig. 4). Further cluster information to look at Appendix see Table 5 at the end of the paper.

Figure 5 indicates network of the most frequently used Sub MeSH Terms during 2000–2007 and 2008–2017. Moreover, Fig. 5 shows the network structures of the 3 most commonly-used MeSH terms. You can visit the web page to see more MeSH terms network structures.

In the Fig. 6, there are four distributions: two of them are constructed with observed data (one for each period of analysis, $P1$ (2000–2007) and $P2$ (2008–2017), and the other two, are theoretical distributions made according to the original definition of Lotka power law: $A(n) = A(1)/n^2$ where:

- $A(n)$ is the number of authors with n papers
- n is de number of works (papers or contributions).
- $A(1)$ is de number of authors with only one paper published in the topic (neurosciences). Sometimes this value is known as constant 'C' if it's expressed in percentage as the proportion of authors with only one contribution or percentage of *transient* authors.

In the original definition of Lotka's law, the power exponent was 2 (or near to). We select this value by simplicity. With this option we have calculated the values of C, in this way for the $P1$ period, $C_{\text{observed}} = 63.5\%$ and $C_{\text{theoric}} = 62.5\%$, i.e. there are similar transients

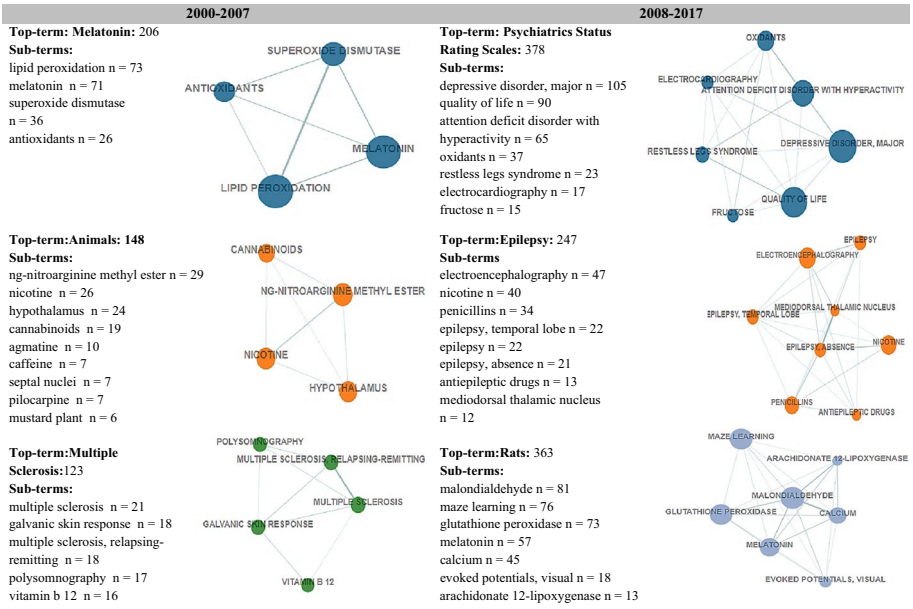

Fig. 5 Network of the most frequently used top and sub MeSH terms during 2000–2007 and 2008–2017

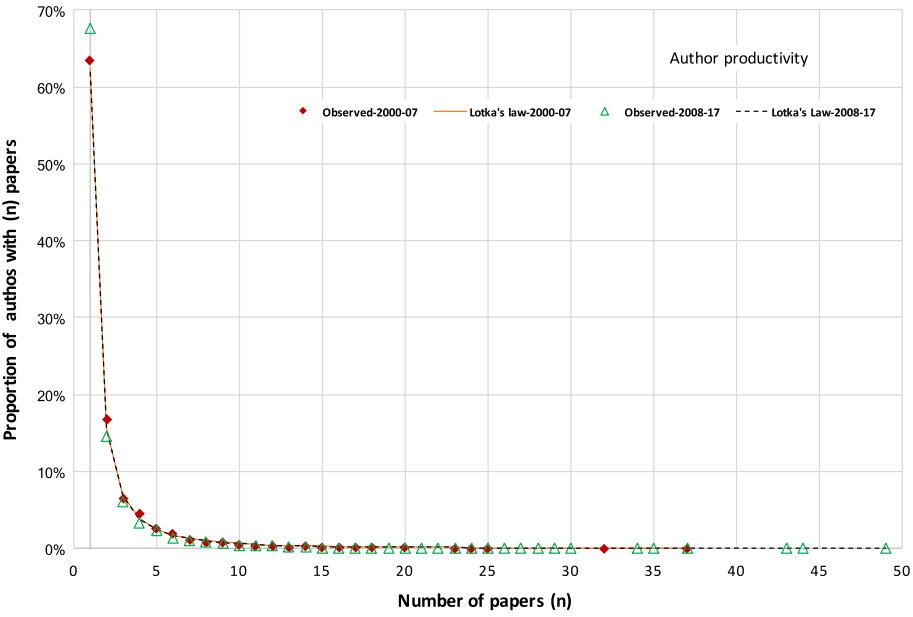

Fig. 6 Author productivity (Lotka power law)

than expected, and for the $P2$, $C_{observed} = 67.7\%$ and $C_{theoric} = 61.9\%$, which means there are more transients authors than expected.

The two observed distributions seems similar—similar productivity—however, the constant C in $P2$ is greater than in $P1$, therefore there are more transient authors in $P2$, and there are more productive authors too (watch the tail of distribution). By the other hand, each of the two Lotka's laws it seems they adjust very well the observed data (see Fig. 6).

According to the Table 4, Author A (% 2.05), Author B (% 1.77), Author C (%1.38) and Author D (% 1.33) are the most widely published authors in 2000–2007, Author K (1.34), Author L (% 1.2), Author M (% 1.17) and Author N (% 1.01) are most widely published authors in 2008–2017. Only author B remains among the most productive in the two periods. For each author, Table 4 display the number of publications in Web of Science database.

Figure 7 visualize data as a Network view, you'll see top and sub clusters circles. The larger the circle, the more articles it contains. When you click on a topic, blue lines appear, showing connections to other topics, and giving you new insights for where you can find useful information. The thicker the line, the stronger the connection and double click on a topic to break it into more specific subtopics.

Figure 8 indicates that in both periods, the articles of the leading authors in terms of highly used MeSH terms in the Pubmed database. In the analyzed period the main authors were: Author A (16 papers/271 citations), Author B (32 papers/2849 citations), Author C (24 papers/621 citations), Author K (24 papers/82 citations), Author M (41 papers/1091 citations) and Author L (20 papers/400 citations).

In the Fig. 8, there are more scattering in the distribution of source journals in the second period of analysis ($P2$) than in the first ($P1$), because in the $P2$ the Turkish literature on neurosciences is distributed on 250 journals by only 160 in the first period. This is shown in the Fig. 6 since the curve in $P2$ is above the other and is more length than the curve in $P1$.

In a different way, at the same number of papers it's necessary a little more source journals for publication, i.e. the fifty percent of the total amount of published papers needs 12 (7.5%) sources in $P1$, by 16 (6.4%) in $P2$. Nerveless the number of works published in the first case is the half of the second period (909 papers by 1850).

Table 4 Most productive authors from 2000 to 2017 in WOS

2000–2007				2008–2017			
Rank	Author	Record count	% of 1807	Rank	Author	Record count	% of 3668
1	Author A	37	2.05	1	Author K	49	1.34
2	Author B	32	1.77	2	Author L	44	1.2
3	Author C	25	1.38	3	Author M	43	1.17
4	Author D	24	1.33	4	Author N	37	1.01
5	Author E	23	1.27	5	Author B	35	0.95
6	Author F	20	1.11	6	Author O	35	0.95
7	Author G	20	1.11	7	Author P	34	0.93
8	Author H	20	1.11	8	Author Q	30	0.82
9	Author I	18	1	9	Author R	30	0.82
10	Author J	18	1	10	Author S	29	0.79

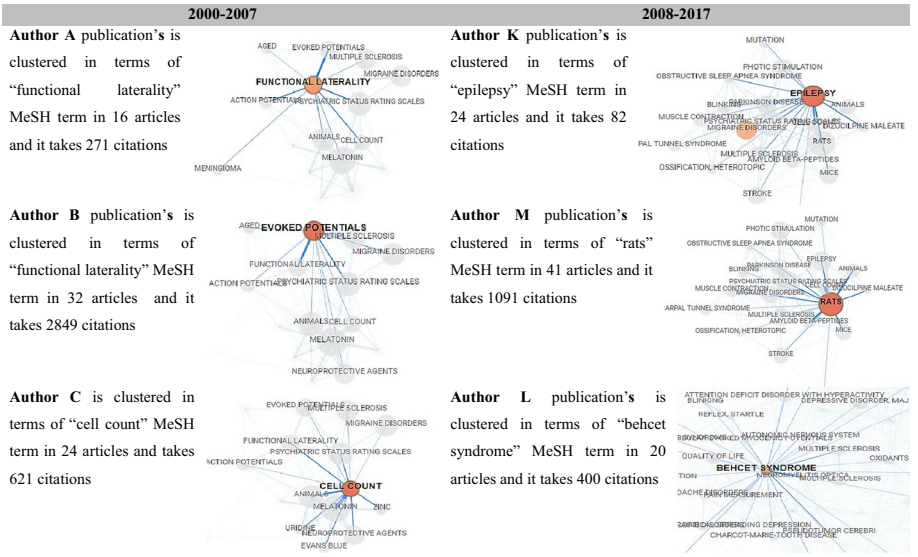

Fig. 7 Top 3 highly productive author's MeSH terms co-occurrence network

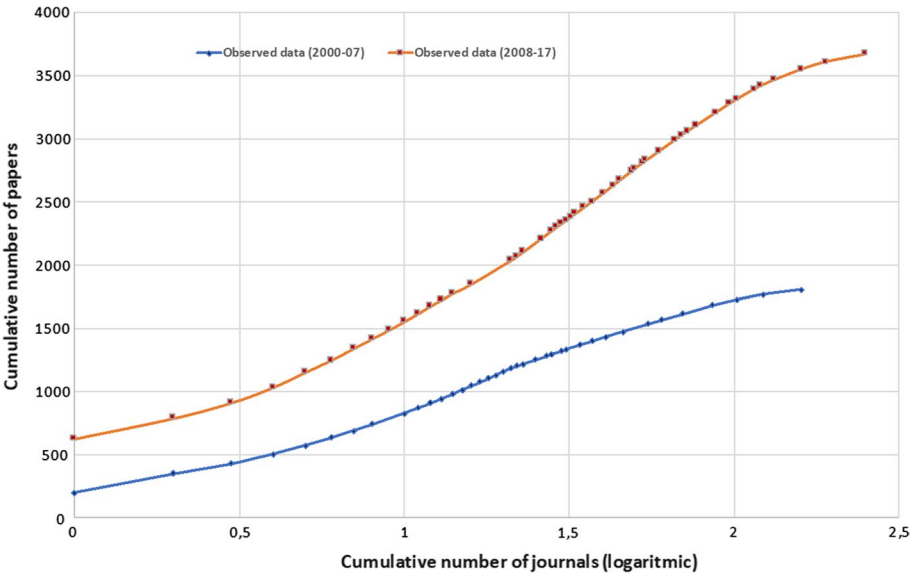

Fig. 8 Journal Productivity (Bradford's law)

As shown in the two graphs (Figs. 6, 8) given above clearly shows that both author productivity and productivity of scientific journals has been increasing markedly during the period 2008–2017 in Turkey.

Although scientific journal of J NEUROL SCI-TURK is the most popular by authors from 2007 to 20017 in Turkey, it is very low in terms of the number of citations it receives. It is shown that this journal in the Q4 level in Journal citation report.

A comparison of 2000–2007 and 2008–2017 content shows that there have been very much changes in the themes covered over the last 17 years. From 2000–2007, the two most prominent journals highlighted in the word cloud were "INT J NEUROSCI" and "J CLIN NEUROSCIENCE" However, from 2008 to 20017, the two most prominent journals highlighted in the word cloud were "J NEUROL SCI-TURK" and "ACTA NEUROL BELG" (see Fig. 9).

Figure 10 shows the most commonly used MeSH terms in scientific journals and its co-occurrence networks, which most articles are published according to two periods. The larger the circle, the more articles it contains.

In the Network view, Fig. 11 indicate network of reference journals. You'll see research journals circles. The larger the circle, the more articles it contains. The thicker the line, the stronger the connection. Here, J NEUROSURG is strongly connected to NEUROSURGERY in 2000–2007 period.

Figure 12 shows that universities are at the same level in the 2000s. However, it is seen that Istanbul University has a clear in a high level in terms of number of publications. The width of the links indicates the co-occurrence weight between two universities in the same article. We used edge weights for analyzing the community detection. (Resolution: 1.0, Modularity: 0137, Number of Communities: 3) Colors correspond to a community analysis performed by Gephi based on the same Louvain algorithm used for the BC analysis. As seen in the graph, universities were grouped in 4 groups. While there were smaller groups in the period of 2000–2007, they were more general during the period of 2008–2017.

The United States is the leading collaborative country in neuroscience output from 2000 to 2017. European countries, such as Germany and the United Kingdom, were also major collaboration with Turkey. With regard to social-health data, it seemed that the

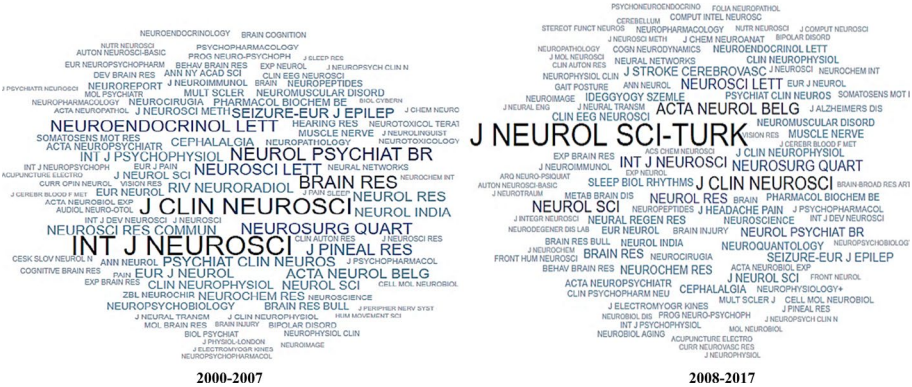

Fig. 9 Word cloud of top 100 journals on Neurosciences in Turkey

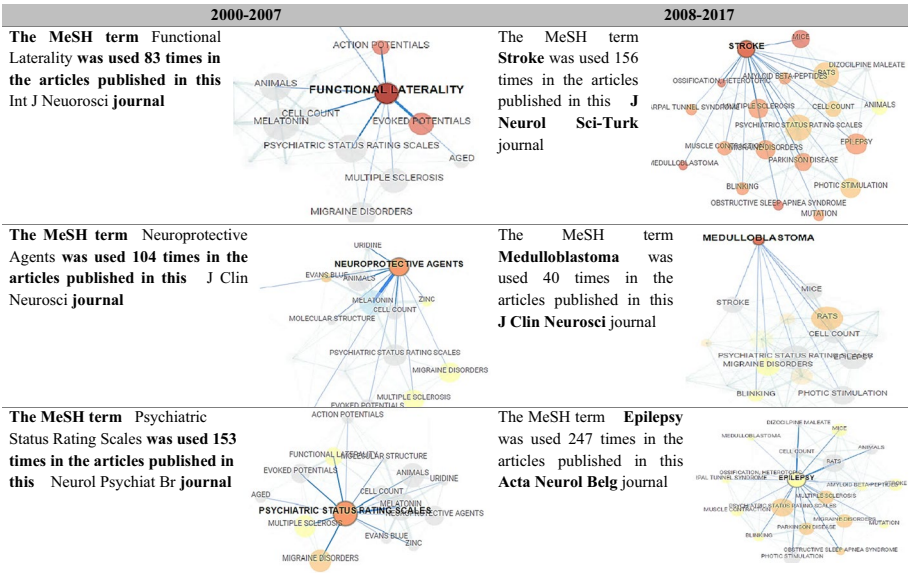

Fig. 10 Top 3 highly productive journal's MeSH terms co-occurrence network

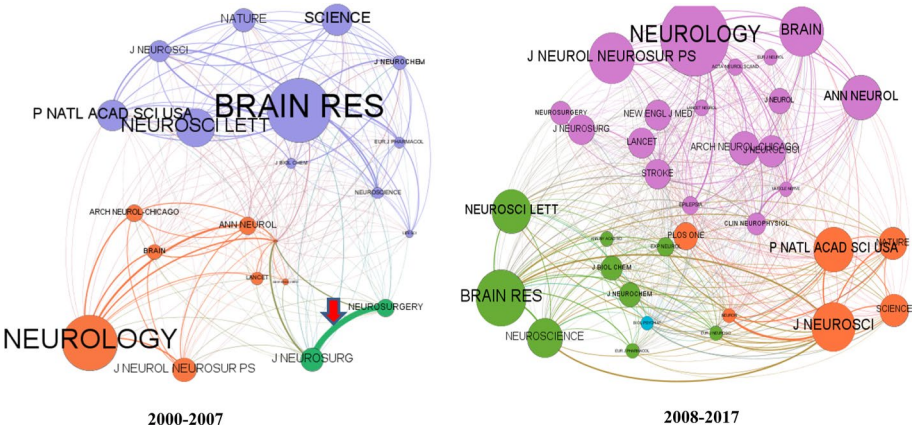

Fig. 11 Network of reference commonly-used journals during 2000–2007 and 2008–2017

publication shares of the most collaborative countries were directly proportional to their respective total per capita expenditure on health. (See Fig. 13).

Figure 14 shows the co-keywords map obtained by using MeSH keywords retrieved via Gephi Software. The size of the nodes is proportional to the number of times a

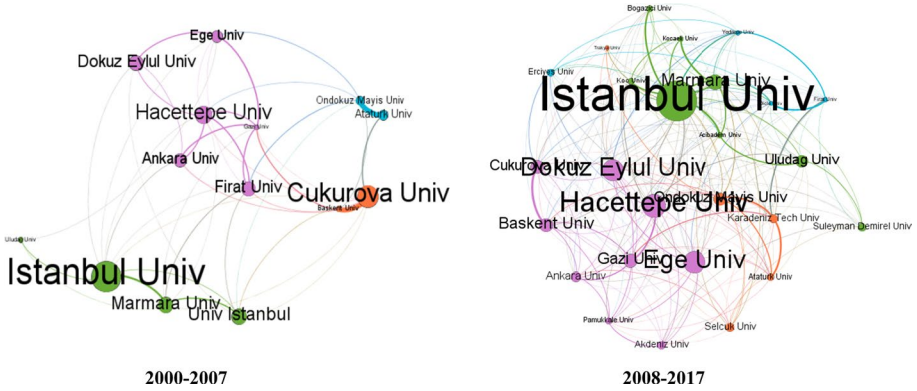

Fig. 12 Network of highly productive universities in Turkey in the field of Neuroscience

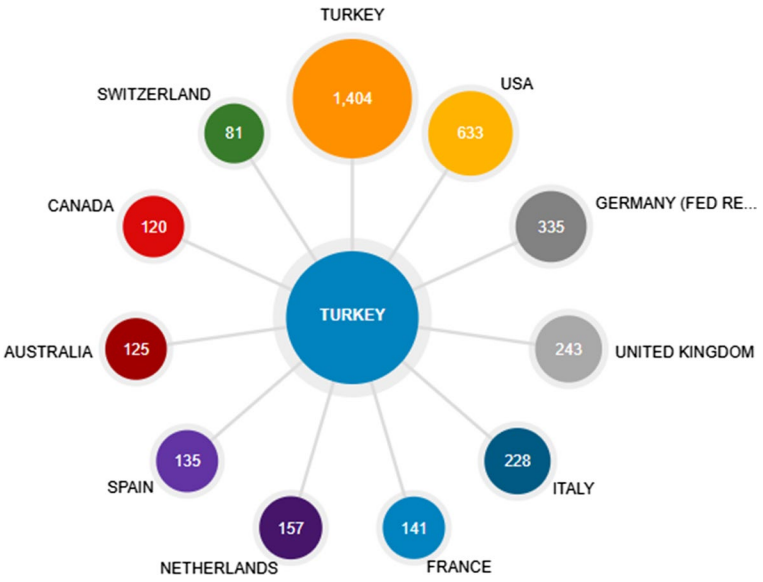

Fig. 13 Top 10 Countries that collaborate with Turkey in Neurosciences 2007–2017

keyword is used in our database. The width of the links indicates the co-occurrence weight between two keywords in the same article.

We used edge weights for analyzing the community detection. (Resolution: 0.75, Modularity: 0225, Modularity with resolution: 0111, Number of Communities: 8) Colors correspond to a community analysis performed by Gephi based on the same Louvain algorithm used for the Bibliographic coupling analysis.

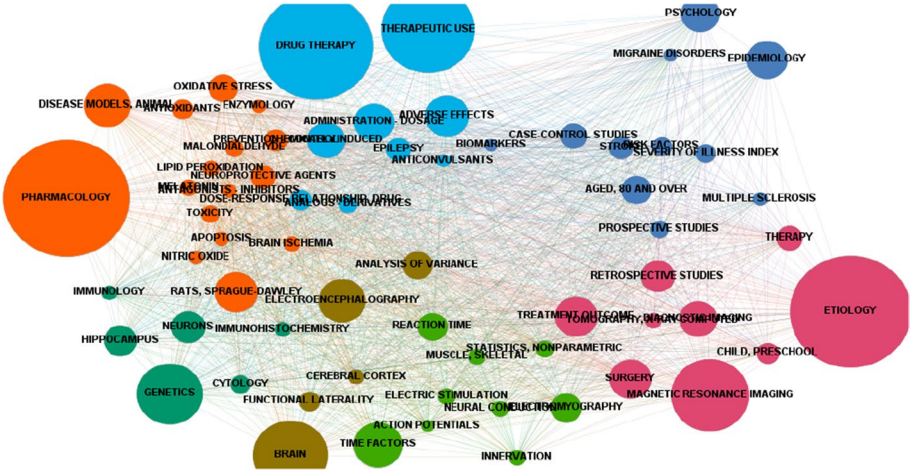

Fig. 14 Co-keywords Network from 2007 to 2017 (Louvain algorithm)

Conclusions

In this paper we used web technologies to create a scientometric picture, using bibliometric analysis methods, of the Neuroscience from its creation in 2000 until 2017 of the Turkish neuroscience indexed at WoS. The aim of this work is show how to provide a good account of the journal's bibliometrics, which will help to quickly identify the journal's main features. The map was built using data from over 5427 articles published from 2000 to 2017. We analyzed the bibliographic record (title, keywords, author, cited references, and abstract) for each article and created a bibliographic coupling network, to link articles sharing at least two common references.

Around 5427 articles of the studied corpus are in the bibliographic coupling network, i.e. sharing at least two references with at least another publication. Each of the remaining publication is isolated, i.e. does not share more than one reference with any other publications in the corpus. We used Louvain Modularity algorithm to detect groups of articles with densely shared links. In the network view, articles belonging to the same group are gathered into nodes, or circles. The circle size is proportional to the number of articles it contains and the thickness of the lines (or chords) between topics indicates how strongly they are connected. Then, we applied the same algorithm to the articles in each topic to split them into subtopics.

From 2000 to 2007 by connecting pairs of journals based on their shared references, there were bibliographic coupling network was created, of which 1510 are in the network out of 1807. The 16 clusters described here are at least 15 papers from the top level. From 2008 to 2017 by connecting together pairs of journals based on common references, a network of bibliographic couples was created 3312 out of 3668 journals are networked. In the 20 clusters described here, there are at least 33 journals in the highest level. After the map

was built, we reviewed the most cited and representative papers in each topic and subtopic to create labels and descriptions. The data analysis and visualization was also completed using BiblioTools.

The analyses also provided information on who is standing on the frontier of this research area: Author A and Author K are the most productive authors. They are spill figures in the cooperation network of authors, which means that other authors are linked (directly or indirectly) to one of them. The journal "J Neurol Sci-Turk" is the key journal publishing on Neuroscience field for Turkish scientific production. The leading institution are Istanbul University, Hacettepe University and Cukurova University are dominating the publication production. In the cooperation network, other universities are linked (directly or indirectly). Author productivity and productivity of scientific journals has been increasing markedly during the period 2008–2017. Additionally Clinical Neurology, Psychiatry, Endocrinology-Metabolism, Physiology Surgery and Pharmacology-pharmacy, are the most collaborative subject to Neurosciences from 2007 to 2017 in Turkey.

We also found strong international collaboration between USA and Europe including Germany, UK, Italy, France, Netherland and Spain. This study will help future web sites to provide more bibliometric information about scientific journals, authors and research fields. As these are evolving very rapidly after each publication issue (e.g. citation counts, new contributing authors, etc.), web tools should be developed to provide the most recent bibliometric updates.

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Appendix

See Table 5.

Table 5 Result of the cluster analysis of publications in the period (2000–2007 and 2008–2017)

Table 2000–2007 MeSH term clusters		Table 2008–2017 MeSH term clusters	
Top clusters	Sub clusters	Top clusters	Sub clusters
Melatonin $N=206$	Lipid peroxidation $N=73$	Psychiatric Status Rating Scales $N=378$	Depressive disorder, major $N=105$
	Melatonin $N=71$		Quality of life $N=90$
	Superoxide dismutase $N=36$		Attention deficit disorder with Hyperactivity $N=65$
	Antioxidants $N=26$		Oxidants $N=37$
Psychiatric Status Rating Scales $N=153$	Schizophrenia $N=68$		Restless legs syndrome $N=23$
	Obsessive–compulsive disorder $N=20$		Electrocardiography $N=17$
	Bruxism $N=18$		Fructose $N=15$
	Leptin $N=18$	Rats $N=363$	Malondialdehyde $N=81$
	Bipolar disorder $N=15$		Maze learning $N=76$
	Behavioral problems $N=12$		Glutathione peroxidase $N=73$
Animals $N=148$	Ng-nitroarginine methyl ester $N=29$		Melatonin $N=57$
	Nicotine $N=26$		Calcium $N=45$
	Hypothalamus $N=24$		Evoked potentials, visual $N=18$
	Cannabinoids $N=19$		Arachidonate 12-lipoxygenase $N=13$
	Agmatine $N=10$	Epilepsy $N=247$	Electroencephalography $N=47$
	Caffeine $N=7$		Nicotine $N=40$
	Septal nuclei $N=7$		Penicillins $N=34$
	Pilocarpine $N=7$		Epilepsy, temporal lobe $N=22$
	Mustard plant $N=6$		Epilepsy $N=22$
Migraine disorders $N=128$	Polymorphism, genetic $N=24$		Epilepsy, absence $N=21$
	Migraine disorders $N=23$		Antiepileptic drugs $N=13$

Table 5 (continued)

Table 2000–2007 MeSH term clusters		Table 2008–2017 MeSH term clusters	
Top clusters	Sub clusters	Top clusters	Sub clusters
	Neuromuscular junction $N=21$		Mediodorsal thalamic nucleus $N=12$
	Epilepsy $N=17$	Photic stimulation $N=220$	Event-related potentials, P300 $N=51$
	Motor neurons $N=16$		Delta rhythm $N=31$
	Migraine without aura $N=12$		Pattern recognition, visual $N=30$
	Spectroscopy, near-infrared $N=7$		Visual perception $N=27$
	Antibodies, protozoan $N=6$		Models, neurological $N=27$
Multiple sclerosis $N=123$	Multiple sclerosis $N=21$		Bipolar disorder $N=12$
	Galvanic skin response $N=18$		Behavioral neuroscience $N=11$
	Multiple sclerosis, relapsing–remitting $N=18$	Multiple sclerosis $N=207$	Multiple sclerosis $N=65$
	Polysomnography $N=17$		Multiple sclerosis $N=56$
	Vitamin B 12 $N=16$		Behcet Syndrome $N=34$
	Carpal tunnel syndrome $N=9$		Neuromyelitis optica $N=19$
	Blinking $N=9$		Autonomic nervous system $N=16$
	Facial paralysis $N=6$	Migraine disorders $N=200$	Migraine disorders $N=37$
Neuroprotective agents $N=104$	Spinal cord injuries $N=24$		Headache disorders $N=37$
	Cerebral infarction $N=20$		Pain measurement $N=27$
	Erythropoietin $N=15$		Cortical spreading depression $N=22$
	Alzheimer disease $N=15$		Vestibular evoked myogenic potentials $N=22$
	Vasospasm, intracranial $N=10$		Charcot-marie-tooth disease $N=21$
	Trigeminal Neuralgia $N=9$		Migraine disorders $N=18$
	Tetrazolium salts $N=6$	MICE $N=175$	Rna, messenger $N=38$
Evoked potentials $N=93$	Alpha rhythm $N=29$		Glioblastoma $N=25$

Table 5 (continued)

Table 2000–2007 MeSH term clusters		Table 2008–2017 MeSH term clusters	
Top clusters	Sub clusters	Top clusters	Sub clusters
	Emotions $N=23$		Chronic subdural hematoma $N=23$
	Evoked potentials $N=17$		Sciatic neuropathy $N=16$
	Neural networks (computer) $N=14$		Erythropoietin $N=15$
	Lewy bodies $N=7$		Neovascularization, physiologic $N=12$
Functional laterality $N=83$	Functional laterality $N=23$	Parkinson disease $N=168$	Alzheimer disease $N=65$
	Intelligence tests $N=16$		Parkinson disease $N=51$
	Intraocular pressure $N=16$		Essential tremor $N=22$
	Dental equipment $N=9$		Biological evolution $N=14$
	Hypersensitivity $N=8$	Stroke $N=156$	Stroke $N=34$
	Osteoprotegerin $N=7$		Thrombolytic therapy $N=27$
Cell count $N=70$	Chickens $N=20$		Intracranial thrombosis $N=20$
	Stereology $N=19$		Neutrophils $N=15$
	Penicillins $N=11$		Rehabilitation $N=15$
	Rat $N=9$		
Action potentials $N=39$	Action Potentials $N=39$		
Aged $N=33$	Aged $N=33$		
Zinc $N=28$	Zinc $N=28$		Hippocampus $N=37$
Cluster 6 evans blue $N=27$	Evans blue $N=27$	Cell count $N=130$	Stereology $N=33$
Meningioma $N=22$	Meningioma $N=22$		Electromagnetic fields $N=23$
Uridine $N=18$	Uridine $N=18$		Spinal cord injuries $N=23$
Molecular structure $N=16$	Molecular structure $N=16$	Animals $N=127$	Analgesics $N=32$
Behcet syndrome $N=14$	Behcet syndrome $N=14$		Docosahexaenoic acids $N=26$
Astrocytes $N=12$	Astrocytes $N=12$		Sensory Gating $N=13$
Guinea pigs $N=12$	Guinea pigs $N=12$		Hypoxia–ischemia, brain $N=12$

Table 5 (continued)

Table 2000–2007 MeSH term clusters		Table 2008–2017 MeSH term clusters	
Top clusters	Sub clusters	Top clusters	Sub clusters
		Muscle contraction $N=110$	Guillain–barre syndrome $N=28$
			Recruitment, Neurophysiological $N=24$
			Tibial nerve $N=20$
		Blinking $N=83$	Deglutition $N=22$
			Reflex, startle $N=16$
			Amyotrophic lateral sclerosis $N=16$
			Blinking $N=14$
			Hemifacial spasm $N=12$
		Amyloid beta-peptides $N=75$	Necrosis $N=19$
			Pseudotumor cerebri $N=13$
			Amyloid beta toxicity $N=12$
		Carpal tunnel syndrome $N=64$	Carpal tunnel syndrome $N=16$
			Ultrasonography $N=12$
			Arthritis, rheumatoid $N=11$
		Mutation $N=61$	Mutation $N=14$
			Posterior leukoencephalopathy syndrome $N=13$
			Dystroglycans $N=12$
		Obstructive sleep apnea syndrome $N=51$	Obstructive sleep apnea Syndrome $N=14$
			Acupuncture therapy $N=12$
			Body position $N=11$
		Medulloblastoma $N=40$	Medulloblastoma $N=40$
		Ossification, heterotopic $N=35$	Ossification, heterotopic $N=35$
		Dizocilpine maleate $N=34$	Dizocilpine maleate $N=34$

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