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Applying clustering coefficient to the pattern of international author collaboration in neuroimmunology and neuroinflammation

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Abstract

Aim: To apply cluster coefficient (CC) to the pattern of international author collaborations in neuroimmunology and neuroinflammation using data from Medline and to visualize results using Google maps and social network analysis (SNA).

Methods: Selecting 2799 abstracts, author names, countries, and keywords on January 22, 2018 from Medline based on keyword neuroimmunology (or neuroinflammation) within the article title since 1982, we reported following features: (1) nation distribution for the 1st author's nationality; (2) eminent journals and authors in the field of neuroimmunology and neuroinflammation; (3) notable keywords defined by authors representing both neuroimmunology and neuroinflammation; and (4) CCs in networks. We programmed Microsoft Excel VBA routines to extract data from Medline and used Google Maps and SNA Pajek software to display graphical representations with an easy-to-read feature for readers.

Results: We found that: (1) the most number of papers in neuroimmunology and neuroinflammation are from the USA (902, 32.23%) and China (363, 12.97%); (2) the productive journals and authors in neuroimmunology and neuroinflammation are *J Neuroinflammation* and *PLoS One*, and Michael T. Heneka (Germany) and Richard M. Ransohoff (USA); (3)

the most linked keywords are interleukin (IL), IL-1beta, and blood brain barrier; (4) author networks present higher CC than those nation networks.

Conclusion: SNA provides wide and deep insight into the relationships among nations in co-author collaboration. The results can help readers in future submission to a journal in neuroimmunology and neuroinflammation.

Keywords: Authorship collaboration, Google Maps, neuroimmunology, neuroinflammation, social network analysis

INTRODUCTION

Neuroimmunology is a field combining neuroscience, the study of the nervous system, and immunology in a review of the immune system. Neuroimmunologists seek to better understand the interactions of these two complex systems during the development of homeostasis and response to injuries. A long-term goal is to further develop our understanding of the pathology of certain neurological diseases[1].

Similarly, neuroinflammation is inflammation of the nervous tissue. It is initiated in response to a variety of cause such as infection, traumatic brain injury, toxic metabolites, or autoimmunity[2]. The central nervous system is typically an immunologically privileged site because peripheral immune cells are blocked by the blood-brain barrier[3,4]. However, the issues including author collaboration and keyword defined by authors are still unclear.

By January 22, 2018, more than 18,282 papers have appeared on PubMed when searching with the keyword (neuroimmunology OR neuroinflammation) and 2885 in the paper title only including the keyword (neuroimmunology [Title] OR neuroinflammation [Title]) since 1982. The issue of which nations dominate the papers published in neuroimmunology and neuroinflammation intrigues us to investigate which keywords are most frequently seen in those articles in the past decades.

Big data is a concept that has evolved from the modern trend of scientism[5]. Many data scientists develop ways to discover new knowledge from the vast quantities of increasingly available information[5]. Even an apocryphal story was often told to explain the concept of co-occurrence between beer and diaper sales[6-8], the way of finding both beer and diaper sales had a strong correlation on Friday is unclear in the literature. All possible pairs of observed goods or services are worth studying the association, which is similar to the keywords and authors in journal papers. Fortunately, social network analysis (SNA)[9-11] can analyze big data for us to investigate the association of any pairs of goods or services in a network.

Authorship collaboration using SNA is an example regarding co-authors in recent years[9] because co-authors among researchers form is a type of social network. Whether the authoring network earns a higher centrality measure (or density) than the national system is required to explore. We are thus interested in using SNA to explore the features in neuroimmunology and neuroinflammation from published papers we observed in Medline library.

Google Maps provide an overall view of geospatial visualization with coordinates of latitude and longitude on a map[12,13]. However, a few appeared in Medline library in search of keyword "google map [Title]" on November 22, 2017. Many papers[9-11] have studied on co-author collaboration in academics, however, none display results with Google Maps and SNA.

Our aims are to apply the clustering coefficient[14] to the pattern of international author collaboration in neuroimmunology and neuroinflammation on the following topics: (1) nation distribution; (2) the most

eminent journals and authors in neuroimmunology and neuroinflammation; (3) the recent research domains defined by authors; and (4) the cluster coefficients (CCs) in different networks.

METHODS

Data sources

We programed Microsoft Excel VBA modules to extract abstracts and their corresponding co-author names as well as author-defined keywords for each article on January 22, 2018, from Medline since 1982. Only those abstracts published by the keyword (neuroimmunology [Title] OR neuroinflammation [Title]) were included. Others like those labeled with Published Erratum, Editorial or without author nation name were excluded from this study. A total of 2885 eligible abstracts were obtained from the Medline.

Data arrangement to fit SNA requirement

Before visualizing our results using SNA, we organized data in compliance with the format and guidelines defined by Pajek software[15]. Microsoft Excel VBA was used to deal with data fitting to the SNA requirement.

Graphical representations to report

Author nations and their relations

Two tables (i.e. columns for publication years and rows for the 1st author nations or journals) were made for presenting the distribution in nation (of journal) for the domain of neuroimmunology and neuroinflammation. The bigger bubble means, the more number of the nodes (i.e. nations, or keywords in this study). The wider line indicates, the stronger relations between the 2 nodes. Community clusters are filled with different colors in bubbles. The most eminent authors were calculated from the Medline library since 1982.

Keywords to present the research domain

If keywords represent the research domain, the stronger relations between the two keywords can be highlighted and linked by SNA. Like the concept of co-occurrence about beer and diaper sales during weekend. The presentation for the bubble and line is similar to the previous section in the interpretation. Keywords defined by the authors were applied to represent the domains in the current study.

Statistical tools and data analyses

Google Maps[16] and SNA Pajek software[15] were used to display and visualized representations for eminent authors and keywords in relation with neuroimmunology and neuroinflammation. Author-made Excel VBA modules were applied to organize the data. CC represents the density of a network and a significant level (> 1.96) is defined by *t*-value as the formula [= $CC \times [(n\text{-}1)/(1\text{-}CC^2)]^{1/2}$], where n = the number of nodes in a network.

In contrast, E-I index is defined by the formula, where EL = the number of external friendship links and IL = the number of internal friendship links[17]. The negative E-I index means a coherence cluster in existence. Similarly, the higher CC indicates many members are members' friends linked to others. Density denotes as the ratio of the linkage members over all possible members.

RESULTS

Author nations and their relations

A total of 2799 eligible papers with complete author nations based on journal article since 1982 are in Table 1. We can see that the most number of articles are from the countries of USA (902, 32.23%) and China (363, 12.97%). The

Table 1. Country/region distribution based on the 1st author for papers published in neuroimmunology and neuroinflammation

Country/region	1982-2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	%	Growth
USA	148	28	35	41	56	74	81	79	84	115	13	902	32.23	0.42
China	5	2	5	7	12	24	38	47	73	128	17	363	12.97	0.67
Germany	23	4	6	10	9	17	17	20	18	26	1	174	6.22	0.43
Italy	19	2	6	9	11	7	15	9	17	33	4	151	5.39	0.51
Canada	26	3	8	7	7	11	12	13	14	16	1	144	5.14	0.35
India	5		5	4	8	5	9	9	21	24	2	97	3.47	0.57
UK	16	1	2	3	4	3	7	7	11	15	2	87	3.11	0.62
France	12	3	7	1	9	1	4	9	9	15		82	2.93	0.28
Spain	6	2	6	2	4	7	12	7	11	17	1	81	2.89	0.45
The Netherlands	11	2	7	4	8	3	8	3	6	7		70	2.50	-0.12
Brazil	1	1	3	2	1	4	5	12	8	17	6	61	2.18	0.73
Australia	1	1		8	3	5	7	12	6	15	1	60	2.14	0.46
Japan	4	3	1	3	9	2	7	9	7	9	1	59	2.11	0.34
Taiwan	2	3	4	2	8	3	3	6	12	9	1	55	1.96	0.32
Sweden	7	1	5		3	4	4	6	4	7		48	1.71	0.26
Israel	9	2	1	2	2	2	3	2	3	1	1	37	1.32	-0.07
Belgium	3			2	2	2	5	3	1	6	1	28	1.00	0.48
Switzerland	3		1	2	1	3	1	2	5	5	1	27	0.96	0.56
Iran	0			4	2	1	1	5	2	9		24	0.86	0.40
Mexico	2		1		2		2		4	7	1	21	0.75	0.54
Others	17	7	7	8	13	18	23	26	44	45	3	228	8.15	0.55
Total	320	65	110	121	174	196	264	286	360	526	57	2799	100.00	0.55

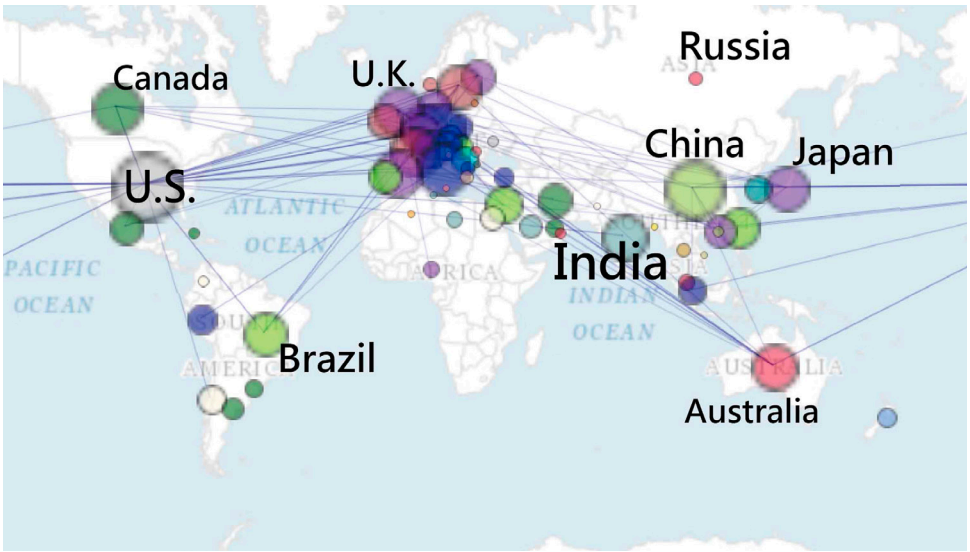

Figure 1. Google Maps on the topic of author collaboration in neuroimmunology and neuroinflammation (cluster coefficient = 0.61)

trend in the number of publications with authorship is present in the column of growth in Table 1. All nations but the Netherlands and Israel showed a positively increase.

The diagram in Figure 1 displays author collaboration among nations. Overall, the highest production in countries are from the USA, China, and Europe [Figure 1]. Any collaborated with others are shown with a blue line. Interested authors are recommended to click the bubble of interest to see details on a website at the reference[18].

The eminent authors in surgery

The most prominent journals and authors with the most number of papers in neuroimmunology and neuroinflammation are *J Neuroinflammation* and *PLoS One* as well as Michael T. Heneka (Germany) and

Table 2. Journal distribution based for papers published in neuroimmunology and neuroinflammation

Journal	1082-2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	%	Growth
J Neuroinflammation	12	3	7	7	32	14	28	27	38	34	1	215	7.90	0.42
PLoS One	0	2	2	4	10	20	15	7	5	7	1	288	10.58	0.05
Brain Behav Immun	3	1	1	4	3	2	6	7	12	26	4	145	5.33	0.62
J Neuroimmunol	24	4	1		3	4	6	6	8	8	1	161	5.91	0.46
J Neurosci	10	2	4	2	4	3	4	4	4	4		140	5.14	-0.09
Neuroscience	5	1		3	2	3	4	6	3	9	1	93	3.42	0.52
J Neurochem	10			4	1	1	4	4	5	4	1	86	3.16	0.51
Mol Neurobiol	0	1			2	2	3	2	9	15		78	2.87	0.54
Exp Neurol	5		4	1	1	2	6	3	6	3	1	71	2.61	0.32
Brain Res	5		2	5		2	1	2	6	6	1	72	2.65	0.37
Mediators Inflamm	1					10	4	5	4	6		66	2.42	0.37
Neurochem Res	1			1	3	1	2	4	6	9	2	61	2.24	0.71
Sci Rep	0			1		1		7	9	10		58	2.13	0.58
Neurobiol Dis	7	1	1	1	2	5		1	3	1	3	60	2.20	0.25
J Alzheimers Dis	3	1	5	1	3		2	1	3	6		60	2.20	0.04
J Neuroimmune Pharmacol	2	2	1		3	8	2	1	2	4		55	2.02	0.01
Glia	5		3	2		3	2		4	4		55	2.02	0.17
J Immunol	6	1	1	3		2	5	3		1		56	2.06	-0.13
Neurochem Int	2		2	1	3	3	2	2	3	3		51	1.87	0.20
Front Cell Neurosci	0					1	7	5		6		42	1.54	0.40
Others	250	47	85	92	121	127	206	218	263	394	45	6061	222.67	0.56
Total	351	66	119	132	193	214	309	315	393	560	61	2722	100.00	0.55

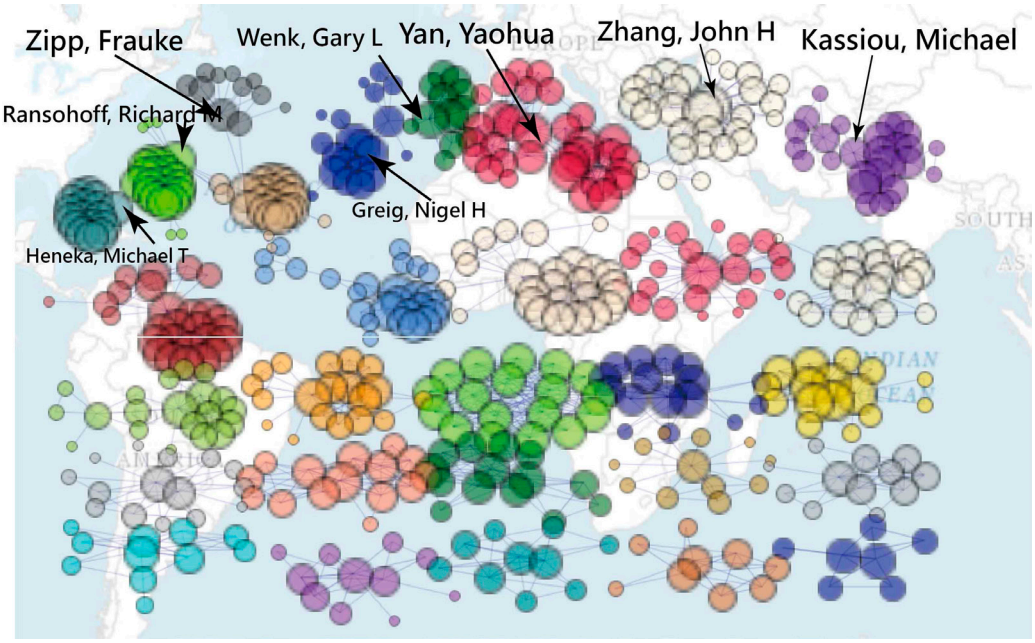

Figure 2. Google Maps on eminent authors in neuroimmunology and neuroinflammation (cluster coefficient = 1.0)

Richard M. Ransohoff (USA) [Table 2 and Figure 2]. The link on website appears at http://www.healthup.org.tw/gps/Neuroimmunologyauthor.htm[19].

Keywords to present the research domain

The most linked keywords are interleukin (IL), IL-1beta, and blood-brain barrier [Figure 3][20]. We can see that the keywords consisting of many clusters with different cluster coefficients.

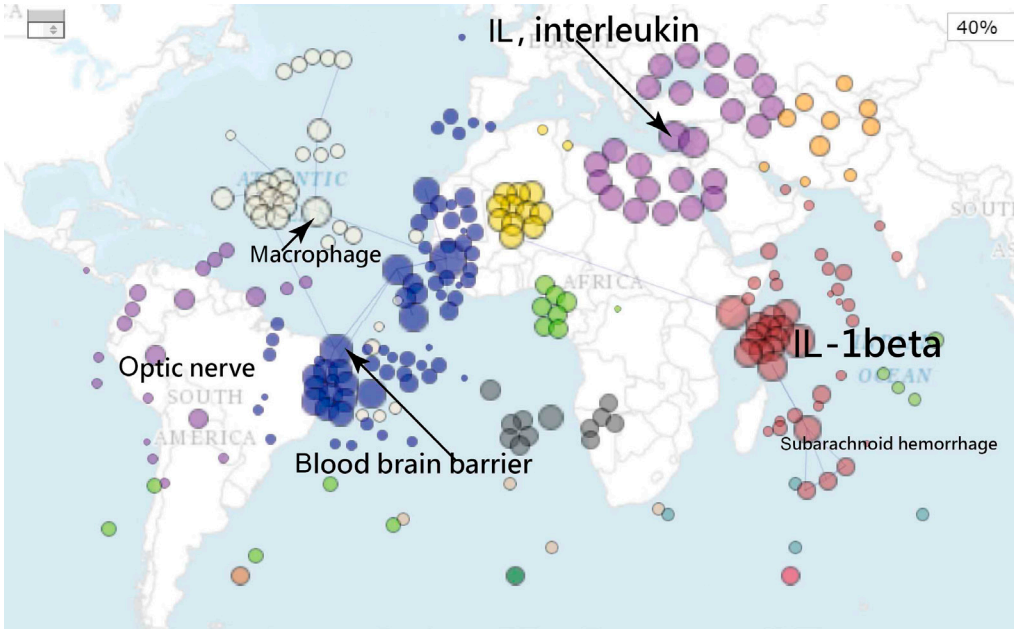

Figure 3. Google Maps on author-defined keywords in neuroimmunology and neuroinflammation (cluster coefficient = 0.60)

Table 3. CCs in each cluster and their relevant indicators

Name	CC	Density	Weighted	EI	Node	Degree	Weighted	*t*-value
Country/region								
Canada	0.61	0.60	0.80	0.12	6	9	12	1.54
Germany	0.60	0.67	2.00	0.64	4	4	12	1.06
UK	0.57	0.76	2.05	0.20	7	16	43	1.55
Italy	0.21	0.47	0.80	0.36	6	7	12	0.43
France	0.20	0.67	1.83	0.67	4	4	11	0.29
India	0.20	0.67	0.83	0.00	4	4	5	0.29
Australia	0.00	0.5	0.50	0.52	4	3	3	0.00
Brazil	0.00	0.67	1.33	0.65	3	2	4	0.00
Chile	0.00	0.67	0.67	0.20	3	2	2	0.00
USA				1.00	1			
China		1.00	2.00	0.75	2	1	2	
The Netherlands		1.00	6.00	0.85	2	1	6	
Taiwan		1.00	2.00	0.60	2	1	2	
Author								
Michael T. Heneka	1.00	1.00	2.00	-0.99	17	136	272	
Richard M. Ransohoff	0.59	0.62	1.25	-0.97	23	158	316	3.35*
Janine Doorduin	0.56	0.30	0.72	-1.00	26	97	235	3.31*
Gary L. Wenk	0.52	0.58	1.65	-0.97	12	38	109	1.93
Dong-Kug Choi	0.45	0.56	1.35	-1.00	16	67	162	1.89
Borja Garcia-Bueno	0.43	0.31	0.70	-1.00	20	58	133	2.02*
John A. Olschowka	0.43	0.61	1.97	-1.00	9	22	71	1.26
Tomas Olsson	0.42	0.37	0.88	-1.00	19	64	150	1.91
Vicente Felipo	0.41	0.54	1.94	-1.00	16	65	233	1.68
Stefan Bittner	0.41	0.51	1.06	-1.00	27	179	373	2.25*
Frederic Dolle	0.41	0.26	0.66	-1.00	27	92	231	2.25*

*Denotes significance when *t*-value greater than 2.0. CC: cluster coefficient.

Cluster coefficients in a network

Each cluster has its cluster coefficient representing the density of a network. We found that author clusters earn higher CC than have nation clusters. Cluster coefficient has a significant effect in comparison with a considerable *t*-value (> 2.0), indicating author network with more significance than those of the nations [Table 3].

DISCUSSION

What this adds to what was known

Many previous types of research[9-11] have investigated co-author collaboration using SNA. The results (the most number of articles from the USA and Europe) are similar to the findings that dominant nations in science come from the USA and Europe[21-23], but China recently has an increasing trend in publication. Referring to the apocryphal story told to discover the co-occurrence about beer and diaper sales[6-8], we presented a novel method incorporating SNA with Google Maps to explore the data. It can be seen that visual representations offered to the readers are rare in literature. Traditionally, it is hard to observe the association of two or more symptoms or entities together that appeared in a network at that moment.

Journal authorship collaboration compared with each other using Google Maps is illustrated in this study. We can see that many links are connecting two nations which indicate a collaboration pattern in paper publication similar to the previous study[7]. Hence, it is easy to observe the phenomena of international author collaboration in neuroimmunology and neuroinflammation, which is inconsistent with the earlier reviews that investigated scientific collaboration of Iranian Psychology and Psychiatry Researchers[23,24].

There are 319 papers with the keyword of SNA when searching Medline on December 21, 2017. There were only two papers[25,26] that incorporated medical subject heading into SNA to release relevant knowledge to readers. However, only a few[27,28] include Google Maps link like we used in our current study. The CCs we illustrated at references[17-20] are called overall CCs. The CCs in figures are 1.0, 0.61, and 0.60, respectively, which is different from the global CCs or individual CC defined by each cluster or by each node. Evidence suggests that in most real-world networks, nodes tend to create a tightly knit groups characterized by a relatively high density of ties; this likelihood tends to be higher than the average probability of a link randomly established between two nodes[15,29].

What it implies and what should be changed?

Scientific publication is one of the objective measurements to evaluate the achievements of a medical specialty or discipline[30]. It is worth using SNA and Google Maps to explore knowledge to readers in the future.

Many algorithms and measures (or indicators) have been developed in SNA to the graphical exploration of our data. If we investigate any author or paper most fits the research domain in a target journal, the centrality measures can be used[9]. It means that the core subject can be analyzed using the centrality measure[11,24] yielded by SNA.

Strengths of this study

The way we incorporated SNA with Google Maps is unique when compared with these published papers[9-11] merely using a single method of SNA. Another strength and feature of this study is that with Google Maps linked to the references[18-20], for interested readers, one can manipulate the link in their own ways on the Google dashboards. The national distribution in Figure 1 allow the reader to easily understand the feature of international author collaborations in neuroimmunology and neuroinflammation. One picture is worth ten thousand words. We hope following studies can report other kinds of information using Google API in the future.

Limitations and future study

The interpretation and generalization of the conclusions of this research should be carried out with caution. First, the data from this study are from Medline for a single journal. It is worth noting that any attempt to generalize the findings of this study should be cautious in the fields of journal domains.

Secondly, although the data were extracted from Medline and carefully dealt with during every linkage as correctly as possible, the original downloaded text file might have some errors in symbols such as period and comma in author address that may lead to some bias in the resulting nation distribution.

Thirdly, there are many algorithms used for SNA. We merely applied separation components showing in figures. Any changes made along the algorithm will cause different pattern.

Fourth, the social network analysis is not subject to the Pajeck software we used in this study. Others such as Ucinet[31] and Gephi[32] are suggested to readers for use in the future.

In conclusion, social network analysis provides wide and deep insight into the relationships among nations in coauthor collaboration. The results can help readers in future submission to a journal in neuroimmunology and neuroinflammation.

DECLARATIONS

Authors' contributions

Drafted the manuscript: Hsu CF
Developed the study concept and design: Chien TW
Analyzed and interpreted the data: Chien TW, Hsu CF, Chow JC
Monitored/supervised the process of this study and helped in responding to the reviewers' advice and comments: Chou W
Read and approved the final manuscript: all authors

Data source and availability

All data were downloaded from Medicine library and in Tables.

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Conflicts of interest

The authors declare that they have no competing interests.

Patient consent

Not applicable.

Ethics approval

Not applicable.

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