International scientific collaboration in research of depression based on social network analysis

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***Abstract*—Background: Depression is harmful to human health and effecting social life seriously and still brings a heavy burden for countries all over the world. Scientific collaboration has become the indispensable choice for progress in the biomedicine field. However, there have been few scientific publications on scientific collaboration in depression research so far. The aim of this study was to measure the activities of scientific collaboration at the level of authors, institutions and countries in depression research.**

Methods: There were 127676 records about depression retrieved from science Citation Index Expanded (SCI-Expanded) of web of science. Additionally, some methods such as social network analysis (SNA), centrality analysis were used in this study.
Results: Collaboration has been increasing at the level of authors, institutions and countries in depression in recent ten years. We selected the top 100 prolific authors, institutions and countries to construct collaborative map respectively. Rush,AJ and Fava,M were the central authors ,Harvard university was the central institution and America was the central country of the whole network in terms of the three kinds of centralities. The rate of economic development in countries affected collaborative behavior.
Conclusion: Based on the results, we should encouraged multiple collaboration types in depression research which not only help researchers to master the forefront research hotspots but also provide scientific basis for clinical research on depression and reasonable suggestions to make policies in order to promote the development of this area.

Keywords- depression; collaboration; SNA

I. INTRODUCTION

Depression is one of the most prevalent psychiatric diseases associated with a significant negative impact on patients' productivity, quality of their lives and cognitive function.[1]According to a recent survey of the World Health Organization, it has been estimated that depression ranks the third in terms of dis-ability life years(DALYs) and will be the number one leading cause of disease and injury burden by 2030,which will surpass that of cardiovascular disease, respiratory system disease and malignant tumor[2].

This terribling situation has been greatly concerned about in global psychiatry field. It has brought a rigorous challenge for worldwide researchers to prevent and control depression and will allocate funding depression research. With crossing and permeating of subjects in biomedicine field, no single one can finish all the specialist tasks. Scientific collaboration becomes the indispensable choice for progression in the biomedicine field because it will improve communication, the sharing of competence and production of new scientific knowledge.

However, there has been little research on scientific collaboration in depression research so far. Therefore, we designed this study to measure the activities of scientific collaboration at the level of authors, institutions and countries in depression research.

II. MATERIALS AND METHOD

The date of this study retrieved from the Science Citation Index Expanded (SCI-Expanded) in web of science. The date contains all types of documents which have the word "depression" in their title, abstract or keywords from 1 January 2003 to 31 December 2012 which covered article, review, meeting abstract and paper, etc. There were totally 127676 records each of which contains title, abstract, author names, institutions, sources and key words. The date includes 254809 authors, 43906 institutions and 176 countries. A paper co-authored by authors from more than one institution was considered inter-institutional collaboration and a paper co-authored by authors from different counties was classified as inter-national collaboration.

In this study, variety of methods such as social network analysis (SNA), centrality analysis were used to find out the connection among authors, institutions and countries in depression research. Theories of SNA was proved to be successful in studies of scientific collaboration network[3][4],because the object of study of SNA is reveal the underlying connection of social entities such as people, organizations and countries. Following the methods of Otte and Rousseau[3],White[5],and Kreschmer and Aguillo[4],SNA was applied to display the structure of collaboration networks. In this study ,we used SNA to analyze the collaborative connection among authors, institutions and countries in depression research. Centrality, which reflects status and rights of activities in their social network is one of the most important content in network analysis. There are three common centrality measures named degree centrality, betweenness centrality and closeness centrality. In the collaborative network, degree centrality is equal to the number of nodes that connect with a central node. It means if an author/institution/country which degree centrality is the highest will be a central author/institution/country of the co-authorship network. Betweenness centrality is the number of the shortest paths that pass through a given node [6].The highest betweenness

centrality indicated an author/institution/country possesses and controls a great deal of research resource. Closeness centrality of a node is equal to reciprocal of the total distance from this node to all other nodes. It means the closer a node is to all other nodes, the higher is its closeness centrality. The lowest closeness centrality indicates an author/institution/country is in a core position of the whole network. UCINET is the main tool and Netdraw for visualizing different network structures is used as supplement[7][8].

III. RESULTS AND ANALYSIS

A. Analysis on Authors 'Collaboration

Achievements in scientific research are published in the form of papers and the status of co-authorship in papers reflects collaboration among authors. M.smith was one of the scientists who studied the growth of co-authorship papers made by multi-author and viewed co-authorship of papers a importance scientometrics indicator researching on collaboration among authors [9].

There were 127676 articles about depression retrieved from the Science Citation Index Expanded (SCI-Expanded)during 2003-2012.Among them, the total number of co-authorship papers was 115584.From the Table 1,the total number of multi-authored papers has increased from 8483 in 2003 to 16772 in 2012 and the percentage rose from 87% to 93% during recent ten years.

In order to show the main co-authorship structure of the network, we selected the top 100 prolific authors during 2003 to 2012 in this study. This threshold resulted in the top 100 prolific authors who must publish 87 co-authorship papers. The figure 1 was a co-authorship map made up of the top 100 authors visualizing the structure of authors' collaboration network. the line value and the distance between two vertices represented the collaborative strength, while thickness of the line represented the number of co-authorship papers. In this authors' collaboration network, the highest degree centrality of Rush,AJ was 428 indicated he had 428 collaborators, so he was the most key author of the co-authorship network. Fava,M had got the highest betweeness centrality which indicated that he possessed and controlled a great deal of research resource. Fava,M had the lowest closeness centrality which indicated he was in a core position of the whole network (see table 2).

B. Analysis on Institutions' Collaboration

There were 90667 papers which belonged to inter-institution collaboration among 127676 papers from SCI during 2003 to 2012.The number of papers has increased from 5371 in 2003 to 122990 in 2012.These papers covered 43906 actual institutions and the appearing frequency of institutions was totally 351245.The largest collaboration in our sample was 'Identification of common variants associated with human hippocampal and intracranial volumes' published in 'Nature Genetics' which involved 136 institutions. Seen from table 3 which described the annual change in institutions, the appearing frequency of institutions grew significantly in 2007 and 2011 and the number of actual institutions increased in the two years while the achievements in scientific research rose respectively in 2007 and 2011.It suggested that the scale of collaboration was related with the output of scientific research positively.

We selected the top 100 institutions with appearing frequencies more than 350 to form a map visualizing the structure of institutions 'collaboration network in the field of depression during 2003 to 2012(see figure 2).In the same way, the distance and thickness of the line between two nodes represented their collaborative strength and the number of collaborative papers respectively. From analysis of centrality, Harvard University had the highest degree centrality, betweenness centrality and the lowest closeness centrality (see table 4). It shows Harvard University was in high level of collaboration.

C. Analysis on Countries' Collaboration

During 2003 to 2012, the total number of countries was 176. From figure 3, we found that the pattern of multi-national collaboration papers was increasing from 5168 papers in 2003 to 12750 papers in 2012.From figure 4, the countries with highest productivity include America, England and Germany and about 53 %publications in depression research originated in America. There were 4586 papers in China, ranked the 10 th place.

We chose the top 100 countries with appearing frequencies more than 19. Figure 5 was the map of the scientific collaboration of the most productive countries in the world. 100 nodes represented 100 productive countries and the number of ties represented the collaborative strength among countries. We selected 20 nodes with the number more than 61.The national names, the number of ties and the product of papers which the 20 nodes corresponded with were listed in the table 5. From the table 5, scientific collaboration was basically correlated with the output of papers positively, but some countries such as France had many ties while not many papers and others such as Brazil had many papers while less ties. We also found the top three countries which had high international collaboration was ranked the top three place in achievements in scientific research while to some extend showed international scientific collaboration had great influence on output of scientific research in this field.

From centrality analysis (see the table 6),That the highest degree centrality of America was 16605 and the highest betweenness centrality of America was 261,while the lowest closeness degree of America was 95 showed America was the center of international scientific collaboration network in the depressive field of the world. The large number of research output maked America a major producer of international publications.

IV. DISCUSSION

Nowadays, with the development of economy and the increasing of social competitive pressure, the number of depressive patients is growing up dramatically. Because of the diversity and complexity of this disease, scientific collaboration plays an indispensable role for progress of depression. Collaboration has increased at the levels of authors, institutions and countries supported by many studies [9] [10] [11].Unfortunately, few publications about scientific collaboration in depression research were reported. This study chose bibliographic date about depression retrieved from the web of science during 2003 to 2012 to construct and analyze the scientific collaboration structure of

depression in the world at the level of authors, institutions and countries based on SNA and found that the scientific collaboration was the first factor to boost the rapid development of this area.

From view of publications in depressive field during 2003 to 2012, the percentage of authored collaboration papers was generally increasing over time and the output of achievements in scientific research by way of collaboration was consistent with the total output. This indicated thatcollaboration among authors to complete research publications has been the main research method. From the results of centrality analysis, Rush,AJ and Fava,M were the central authors of the whole network which indicated that they were the most influential persons in the field of depression research in the world. According to it, we can easily select the leader of this field of learning.

From the level of multi-institutional collaboration, with actual collaborative institutions increasing, the output of achievements in scientific research was on the rise according to the date from 2003 to 2012 which showed the output of scientific publications kept pace with actual collaborative institutions. That some research institutions which were devoted to depression repeated greatly showed their research ability was gradually strengthening. Harvard University's centrality is the highest which indicated it possessed and controlled a great deal of research resource, so it became the central of multi-institutional collaboration in depressive field all over the world.

From the level of multi-national collaboration, America whose centrality was the highest was in the most central position. Judging from analysis above, each of country 's scientific collaboration was basically correlated with its output of scientific research positively, but as the date noted, some prolific countries need to strengthen their national collaboration and more collaborative countries need enforce their ability of scientific research output.

From view of collaboration in authors, institutions and countries, America has been the center in the field of depression research. That the ability of international collaboration and the output of scientific research were the highest all over the world closely related with the rate of economic development which affect the collaboration behavior. Higher income countries prefer to collaborate with each other and lower income countries prefer to collaborate with higher incomes in order to yield high quality productions[12].

This study has selected 100 prolific authors, ,institutions and countries .If the whole authors, institutions and countries were chosen, collaboration network can not analyze them.

In conclusion, this study described the collaboration behaviors in depression research at the level of authors, institutions and countries. Collaboration can offer scientific evidences and reasonable suggestions as the basis of making polices to guide finance depression research in the future .in the subsequent study, we will select other important mental disease to research on their collaboration behavior in order to acquire more valuable information and promote the rapid development of the field of psychiatry.

V. FIGURES AND TABLES

Table 1 SCIENTIFIC PAPERS CO-AUTHORED IN DEPRESSIVE FIELD

Year	Total papers	Co-authored papers	The percentage of co-authorship（%）
2003	8483	6880	81.1
2004	9920	8779	88.5
2005	10294	9203	89.4
2006	11393	10163	89.2
2007	12336	11065	89.7
2008	13603	12311	90.5
2009	14190	12913	91.0
2010	14993	13764	91.8
2011	15692	14531	92.6
2012	16772	15648	93.3

TABLE 2 TOP 10 AUTHORS ON CENTRALITY MEASURES IN COLLABORATION NETWORK IN DEPRESSION

Degree	Score	Betweenness	Score	Closeness	Score
Rush, AJ	428	Fava, M	229	Fava, M	326
Fava, M	408	Lee, S	189	Kessler, RC	327
Trivedi, MH	407	Kessler, RC	155	Frank, E	328
Wisniewski, SR	386	Frank, E	147	Thase, ME	330
Nierenberg, AA	270	Thase, ME	132	Bauer, M	331
Thase, ME	232	Nolen, WA	121	Rush, AJ	331
Penninx, BWJH	157	Rush, AJ	103	Nolen, WA	335
De Graaf, R	147	Reynolds, CF	94	Nierenberg, AA	337
Ormel, J	144	Bauer, M	84	Calabrese, JR	337
Frank, E	139	Unutzer, J	76	Demyttenaere, K	338

TABLE 3 ANNUAL INSTITUTIONAL CHANGE IN DEPRESSIVE FIELD

Year	Frequency of institutions	Actual institutions	Number of papers
2003	19425	5155	8483
2004	23494	5966	9920
2005	24977	6325	10294
2006	26078	6287	11393
2007	32266	7938	12336
2008	37153	8972	13603
2009	39902	9100	14190
2010	44172	10314	14993
2011	50387	11008	15692
2012	53391	11881	16772

TABLE 4 TOP 10 INSTITUTIONS ON CENTRALITY MEASURES IN COLLABORATION NETWORK IN DEPRESSION

Degree	Score	Betweenness	Score	Closeness	Score
Harvard Univ	3143	Harvard Univ	36	Harvard Univ	101
Univ Pittsburgh	2778	Johns Hopkins Univ	31	Univ Toronto	103
Columbia Univ	2477	Univ Toronto	30	Johns Hopkins Univ	103
Univ Calif Los Angeles	1974	Brown Univ	29	Columbia Univ	104
Univ Penn	1628	Columbia Univ	29	Kings Coll London	105
Massachusetts Gen Hosp	1572	Kings Coll London	28	NIMH	106
Univ Washington	1491	NIMH	28	Univ Calif Los Angeles	106
Duke Univ	1411	Univ Calif Los Angeles	25	Univ Washington	107
Univ Calif San Diego	1400	Univ Calif San Diego	25	Univ Calif San Diego	107
Stanford Univ	1372	Univ N Carolina	25	Brown Univ	107

TABLE 5 THE RELATION BETWEEN INTERNATIONAL COLLABORATION AND SCIENTIFIC PRODUCTION

Collaboration		Country	Production	
Ranks	*Lines*		*Papers*	*Ranks*
1	97	USA	46668	1
2	93	England	10785	2
3	92	Germany	10143	3
4	83	France	4814	9
5	82	Australia	6434	5
6	80	Canada	7914	4
7	80	Italy	5608	6
8	77	Spain	3625	11
9	76	Switzerland	2436	14
10	76	Netherlands	5358	7
11	72	Japan	4958	8
12	71	India	1488	16
13	70	Belgium	1644	15
14	69	China	4586	10
15	69	Austria	1251	18
16	69	South Africa	587	20
17	67	Sweden	2918	13
18	67	Scotland	1420	17
19	66	Brazil	3006	12
20	61	Ireland	1013	19

TABLE 6 TOP 10 COUNTRIES ON CENTRALITY MEASURES IN COLLABORATION NETWORK IN DEPRESSION

Degree	Score	Betweenness	Score	Closeness	Score
USA	16605	USA	261	USA	95
England	9473	England	191	Germany	99
Germany	7350	Germany	176	England	99
Canada	5213	Italy	141	Australia	105
Italy	5078	Australia	124	Canada	106
Netherlands	4556	Canada	121	Italy	108
France	4539	France	108	France	108
Australia	3817	Spain	101	Spain	111
Spain	3460	Switzerland	88	Switzerland	113
Switzerland	2992	Japan	80	Japan	114

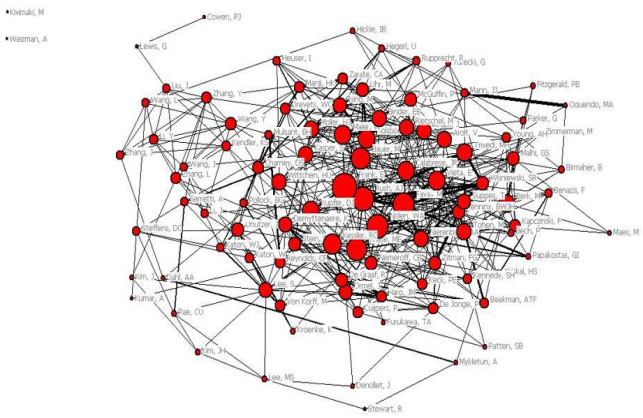

FIGURE 1 THE STRUCTURE MAP OF AUTHORS' COLLABORATION NETWORK IN DEPRESSIVE FIELD DURING 2003-2012

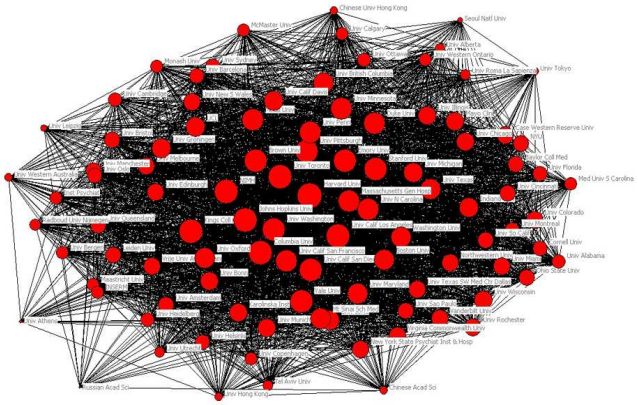

FIGURE 2 THE STRUCTURE MAP OF THE INSTITUTIONS' COLLABRATION NETWORK IN DEPRESSIVE FIELD DURING 2003-2012

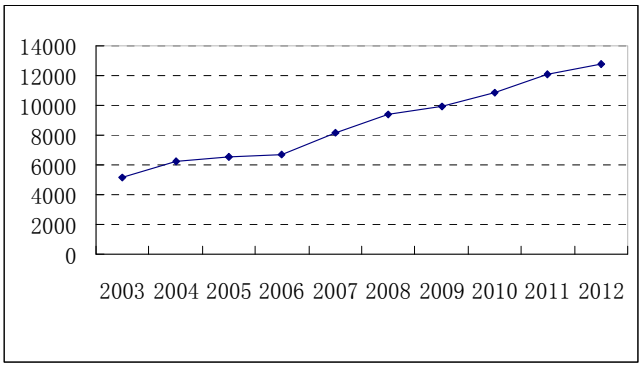

FIGURE 3 DISTRIBUTION OF COUNTRIES' COLLABORATION PUBLICATIONS IN DEPRESSIVE FIELD

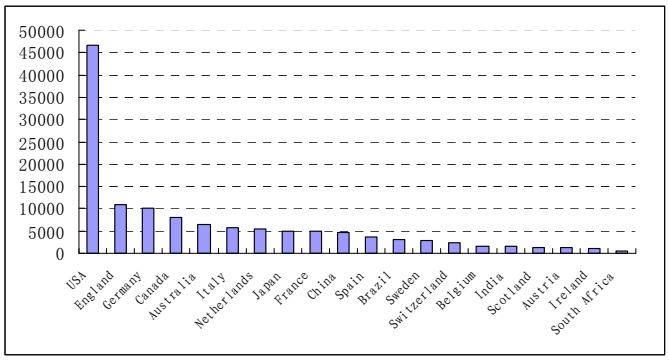

FIGURE 4 NATIONAL DISTRIBUTION IN DEPRESSIVE FIELD

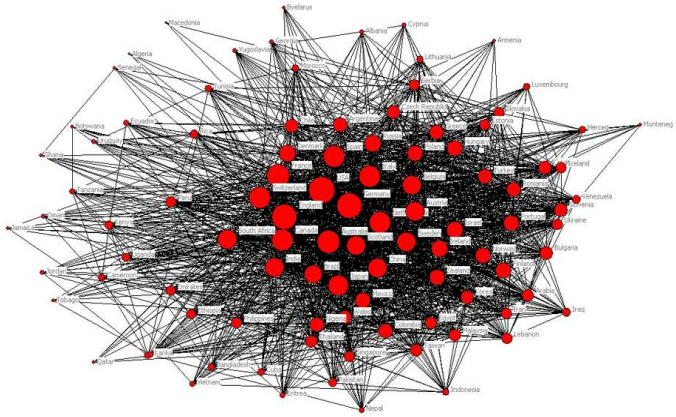

FIGURE 5 THE STRUCTURE MAP OF THE COUNTRIES COLLABORATION NETWORK IN DEPRESSIVE FIELD DURING 2003 TO 2012

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