Identification and analysis of classic articles and sleeping beauties in neurosciences

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This study aims to evaluate the properties of neuroscience articles highly cited at present, based on the overall neuroscience literature. Results reveal 387 classic articles that have been cited at least 1000 times from the Web of Science since their publication to the end of 2016. Data showed that the 1990s was the most prolific decade in terms of classic articles published, and that USA, UK and Canada were the major contributors. Harvard University and Stanford University, USA, were the most dominant institutes. Moreover, there was one classic sleeping beauty, a paper published with scarce citations for a long period before being cited frequently.

Keywords: Bibliometrics, classic articles, literature survey, neurosciences, sleeping beauties.

PREVIOUSLY reports have mapped the neuroscience literature published during 2006–2015 (ref. 1) and identified the 100 all-time most cited neuroscience articles[2]. However, the former study only focused on an arbitrary period of 10 years, whereas the latter did not account for the fact that some of the identified articles were outdated and rarely cited in recent years. Moreover, these studies did not evaluate the presence of sleeping beauties, which are research articles that remain uncited for a period of time before being frequently cited[3], among the highly cited neuroscience articles.

Therefore, the present study evaluates the properties of highly cited articles, and identifies sleeping beauties among them, if any, based on the overall neuroscience literature.

Methodology

Bibliographic data were collected from the Science Citation Index Expanded (SCI-EXPANDED) database of the Web of Science (WoS) from Clarivate Analytics (updated on 28 August 2017). There were 258 journals listed in WoS category of neurosciences in 2016. A total of 1,330,036 documents including 837,290 articles from 1900 to 2016 were found in the category of neurosciences. We recorded the total number of times an article was cited from the WoS Core Collection since its date of publication to the end of 2016 and denoted it as TC_{2016} (ref. 4). Classic articles were defined as having $TC_{2016} \geq 1000$ (refs 5, 6). The advantage of using TC_{2016} compared to the usual measure of all-time total citations in the WoS Core Collection lies in its invariance, for it is not updated over time[5]. This also applies to C_{2016}, the total number of citations of an article in 2016 only[4]. Therefore, TC_{2016}, C_{2016} and their derivatives can be checked and reproduced.

We downloaded all records and the number of citations for each article for each year into spreadsheets, and processed them using Microsoft Excel 2013 (ref. 7).

In subsequent analyses, articles originating from England, Scotland, Northern Ireland and Wales were grouped together as being from the United Kingdom. Articles from the Federal Republic of Germany (Fed Rep Ger) were reclassified as being from Germany[8].

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Results and discussion

Document type and language of publication

Analysis of document types and their citations per publication has been done earlier[9]. A total of 637 classic publications with $TC_{2016} \geq 1000$ in the WoS category of neurosciences were found within six document types indexed in the WoS. The most used document type was articles (61% of 637 publications) followed by reviews (35%) (Table 1). Articles and reviews had similar citations per publication (CPP_{2016}): 1702 and 1622 respectively. Only articles were used for subsequent analysis because they included complete research ideas and results[10]. We identified 387 classic articles in the category of neurosciences, all of which were published in English.

Publication year

Figure 1 shows the distribution of these 387 classic articles and the citations per publication ($CPP_{2016} = TC_{2016}/TP$,

Table 1. Citations and authors according to document type

Document type	TP	Percentage	TC_{2016}	CPP_{2016}	AU	APP
Article	387	61	658,635	1,702	1,795	4.6
Review	225	35	364,929	1,622	634	2.8
Proceedings paper	10	1.6	15,411	1,541	52	5.2
Editorial material	12	1.9	18,186	1,516	28	2.3
Note	13	2.0	18,232	1,402	41	3.2
Book chapter	5	0.78	5,455	1,091	12	2.4

TP, Number of publications; AU, Number of authors; APP, Number of authors per publication; TC_{2016}, Total citations since publication to the end of 2016; CPP_{2016}, Citations per publication (TC_{2016}/TP).

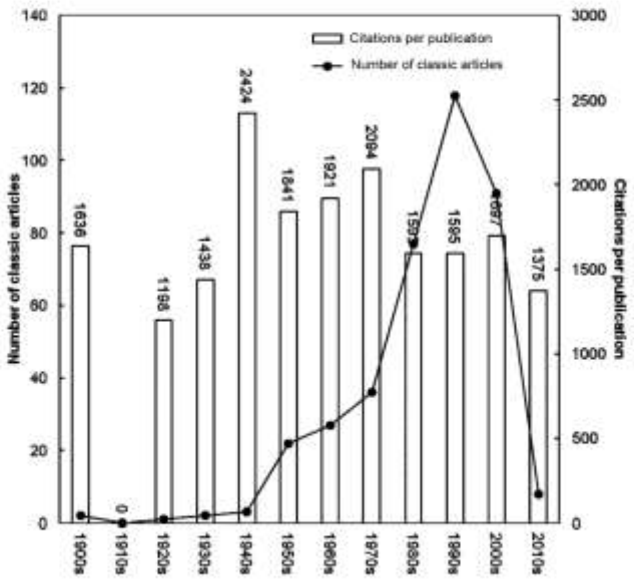

Figure 1. Number of articles and citations per publication by decade.

where TP is the number of publications) by decade[8]. Only two classic articles were found in the decade of the 1900s, and no classic article was identified in the most recent four years (2013–2016).

The 1990s was the most prolific period in terms of classic articles in neurosciences, which was different from the WoS categories of surgery[6] and psychology[5]. Besides, the decade of the 1940s had three articles with higher CPP_{2016} of 2424. The earliest classic article in neurosciences was 'On the local reactions of the arterial wall to changes of internal pressure'[11] with TC_{2016} of 1215. The latest classic article was found in 2012, entitled 'Spurious but systematic correlations in functional connectivity MRI networks arise from subject motion'[12] with TC_{2016} of 1298.

Journals

A total of 258 journals were listed in the WoS category of neurosciences in 2016. The 387 classic articles were published in 52 of these journals, and in eight other neuroscience journals that were no longer tracked by the WoS category of neurosciences as of 2016. Table 2 shows the top 17 productive journals with more than five classic articles. The *Journal of Physiology–London* published the largest number of classic articles, i.e. 42 (11% of 387), followed by the *Journal of Neuroscience* with 37 and *NeuroImage* with 29, while their IF_{2016} was 4.739 (rank 50th of 258 neurosciences journals), 5.988 (29/258) and 5.835 (31/258) respectively. In Table 2, only *Biological Psychiatry* explicitly accepts replication studies[13]. Figure 2 is a scatter plot between the number of classic articles and IF_{2016} (ref. 9) – while there appeared no linear relationship between the two variables, all journals with at least 20 classic articles had IF_{2016} of three or more.

Countries

Among the 322 classic articles with author information, 71 (22% of 322 articles) involved international collaborations. Table 3 lists the 11 countries that published more than five classic articles in neurosciences – USA convincingly took the first place by all the indicators used, followed by the UK and Canada. USA published internationally collaborative articles with 18 countries, i.e. UK (14 articles), Canada (13), Germany (10), Sweden (7), France (5), The Netherlands (5), Israel (4), Italy (4), Japan (4), Switzerland (4), Australia (3), Austria (3), Spain (3), Ireland (2), and one each for Czech Republic, Finland, Poland and Taiwan respectively. Researchers from the US contributed to 215 of 322 classic articles, followed distantly by the UK with 64 articles, Canada with 33 and Germany with 24. The predominance of USA is consistent with research evaluation in the neuroimaging field[14].

Institutions

Six indicators, i.e. total articles, independent articles, collaborative articles, first-author articles, corresponding-author articles, and single-author articles were used to compare the publication performance of institutions[15]. Altogether, 322 classic articles with author affiliations in SCI-EXPANDED were analysed. Supplementary Table 1 shows the 13 most productive institutions with ten or

Table 2. Top 17 journals in the WoS category of neurosciences

Journal	TP (%)	IF_{2016} (R)
Journal of Physiology–London	42 (11)	4.739 (50)
Journal of Neuroscience	37 (10)	5.988 (29)
NeuroImage	29 (7.5)	5.835 (31)
Neuron	26 (6.7)	14.024 (6)
Nature Neuroscience	23 (5.9)	17.839 (2)
Annals of Neurology	22 (5.7)	9.89 (14)
Journal of Comparative Neurology	22 (5.7)	3.266 (102)
Pain	17 (4.4)	5.445 (32)
Journal of Neurophysiology	16 (4.1)	2.396 (163)
Brain	11 (2.8)	10.292 (13)
Human Brain Mapping	10 (2.6)	4.53 (57)
Journal of Neurochemistry	10 (2.6)	4.083 (65)
Brain Research	9 (2.3)	2.746 (133)
Biological Psychiatry	8 (2.1)	11.412 (10)
Journal of Neuroscience Methods	8 (2.1)	2.554 (146)
Behavioral and Brain Sciences	6 (1.6)	14.20 (5)
Journal of Cerebral Blood Flow and Metabolism	6 (1.6)	5.081 (41)

TP, Total number of classic articles; IF_{2016}, Impact factor for 2016; R, Rank of IF_{2016} in WoS category of neurosciences.

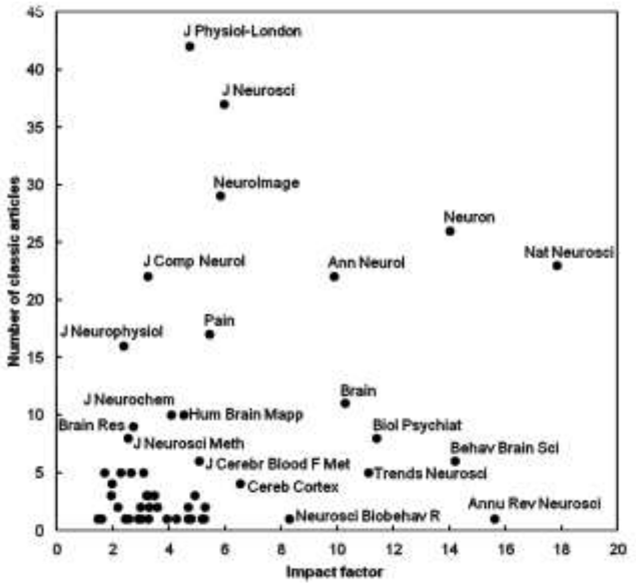

Figure 2. Scatter plot of the number of classic articles against impact factors of their publishing journals.

more classic articles in the category of neurosciences. Harvard University, USA was ranked first for the number of classic articles and the number of institutionally collaborative articles. Ten of the 13 most productive universities were located in the US. Massachusetts General Hospital had no single-institute and single-author classic articles in neurosciences. Harvard University and Massachusetts General Hospital were the most frequent research partners in classic articles in neurosciences. It has been reported that Harvard University was the most collaborative institute in the WoS category of psychology[5]. Stanford University, USA published 18 classic articles in the category of neurosciences and was ranked top for three indicators: first-author, corresponding-author and single-author articles. Washington University, USA published the most institutional-independent classic articles.

Authors

There were 119 classic articles (31% of the 387 classic articles) with missing corresponding author information in the WoS database. Among the 1531 authors contributing to 387 classic articles in neurosciences, 1374 (90% of 1531 authors) published only one classic article in neurosciences, 105 authors (6.9%) published two and 33 (2.2%) published three. Following Ho[16], we applied four bibliometric indicators – the total number of classic articles, first-author articles, corresponding-author articles and single-author articles, to evaluate these classic authors. Supplementary Table 2 lists the 14 authors who published five or more classic articles using these four indicators. The first author in an article is normally considered the person who contributes most to the work, including conducting the research and writing the manuscript[17,18]. The corresponding author is responsible for responding to requests for information and copies of relevant papers[19]. SCI-EXPANDED recorded the names of the corresponding authors for only 268 of the 387 classic articles in neurosciences. There were a total of 217 classic articles (81% of 268 articles) with the first author also being the corresponding author. Considering the overall contribution to the classic articles, K. J. Friston (Wellcome Trust Centre for Neuroimaging, UK) was the most prolific, as he had published 13 classic articles, including 6 first-author articles and 5 corresponding-author articles (Supplementary Table 2). Meanwhile,

Table 3. Top 11 productive countries with five or more classic articles

		Rank (%)					
Country	TP	TP	IP	CP	FP	RP	SP
USA	215	1 (67)	1 (66)	1 (69)	1 (59)	1 (58)	1 (48)
UK	64	2 (20)	2 (14)	2 (39)	2 (15)	2 (15)	2 (13)
Canada	33	3 (10)	3 (4.4)	3 (31)	3 (7.1)	3 (6.9)	3 (6.5)
Germany	24	4 (7.5)	4 (3.6)	4 (21)	4 (4.3)	4 (4.7)	3 (6.5)
France	12	5 (3.7)	6 (1.6)	5 (11)	6 (1.6)	6 (1.8)	7 (3.2)
The Netherlands	12	5 (3.7)	5 (2.4)	8 (8.5)	5 (2.8)	5 (3.3)	3 (6.5)
Italy	11	7 (3.4)	7 (1.2)	5 (11)	6 (1.6)	6 (1.8)	7 (3.2)
Japan	8	8 (2.5)	7 (1.2)	9 (7.0)	8 (0.93)	8 (1.1)	3 (6.5)
Sweden	8	8 (2.5)	N/A	5 (11)	13 (0.62)	15 (0.36)	N/A
Austria	6	10 (1.9)	11 (0.40)	9 (7.0)	8 (0.93)	10 (0.73)	N/A
Switzerland	6	10 (1.9)	10 (0.80)	12 (5.6)	8 (0.93)	10 (0.73)	N/A

TP, Total number of classic articles; IP, Single-institute articles; CP, Institutionally collaborative articles; FP, First-author articles; RP, Corresponding-author articles; SP, Single-author articles.

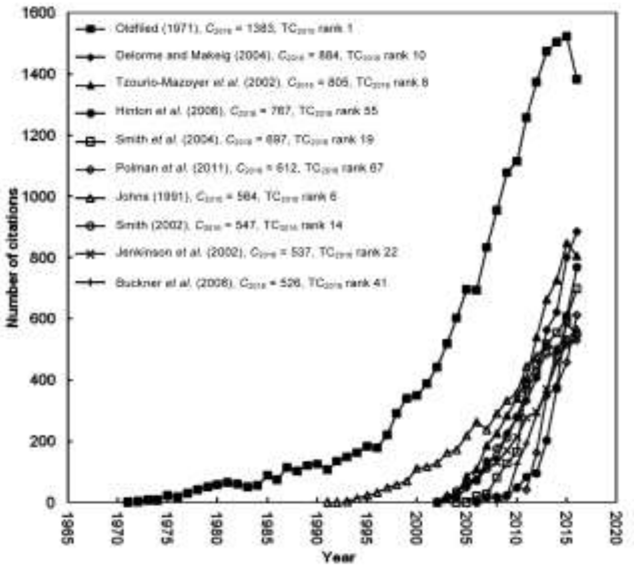

Figure 3. Citation history of the top 10 classic articles with $C_{2016} > 500$. C_{2016}, Citations in 2016 and TC_{2016}, Total citations since publication to the end of 2016.

D. W. Choi (Stanford University) had published three single-author classic articles. Seven classic authors in neurosciences were Nobel Prize winners, including L. N. Cooper (Physics in 1972), A. L. Hodgkin and A. F. Huxley (Physiology or Medicine, 1963), B. Katz (Physiology or Medicine, 1970), D. H. Hubel and T. N. Wiesel (Physiology or Medicine, 1981) and B. Sakmann (Physiology or Medicine, 1991). They have authored 22 (5.7%) of the 387 classic articles.

The most cited classic articles in 2016

From Figures 3 and 4 as well as Supplementary Table 3, it is clear that one particular article took centre stage: the influential paper reporting an assessment tool on handedness by Oldfield[20]. It received more than 1000 citations per year during the period of 2009–2016 and has accumulated more than 19,000 citations in total. It provided an important tool for researchers to assess the homogeneity of the subjects recruited with regard to handedness.

Two articles that also had high C_{2016} and TCPY (i.e. TC_{2016}/year since publication) were authored by Delorme and Makeig[21], and Tzourio-Mazoyer *et al.*[22]. The former article introduced a tool for processing neuroimaging data collected from electroencephalography (EEG), whereas the latter introduced a tool for automatic labelling of brain structures within a standardized brain coordinate system. These tools are important for the majority of researchers who need to analyse neuroimaging data.

Supplementary Table 3 shows the top 20 impact articles in 2016. All articles introduced either psychosocial tools for subject assessment, or algorithms and tools for processing data generated from neuroscience research. There was one exception – the article by Seeley *et al.*[23] reported the discovery of two distinct brain networks responsible for salience processing and executive control – which advanced understanding of human brain function.

Classic sleeping beauties in the Web of Science category of neurosciences

A typical sleeping beauty in the scientific literature is 'Versuche über Plflanzenhybriden'[24]. This article was described as a sleeping beauty because its significance was not appreciated, and therefore citations did not accumulate for over 30 years[25]. Van Raan[3] defined the three characteristics of such publications to be depth of sleep, length of sleep and awakening intensity. Furthermore, long sleep and high impact sleeping beauties have also been discussed[26]. Among the 387 classic articles identified in the present study, one article published by Yerkes and Dodson[27] was identified as a classic sleeping beauty.

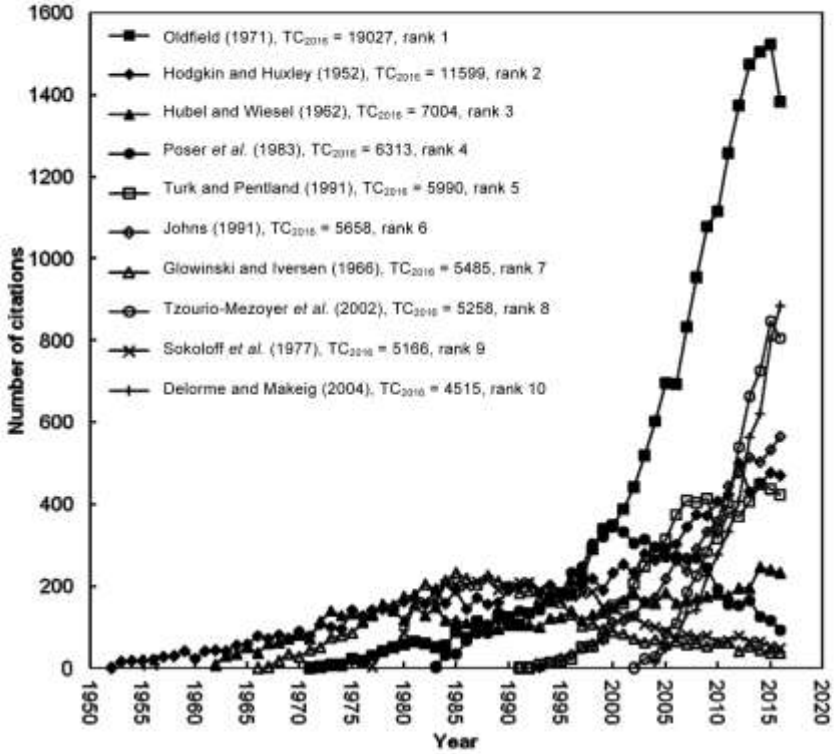

Figure 4. Citation history of the top 10 classic articles with TC_{2016} >4500.

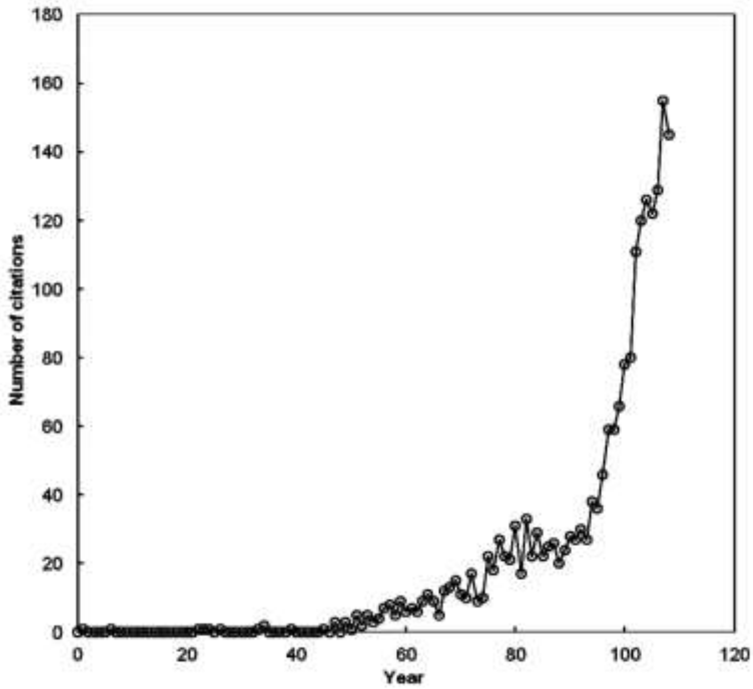

Figure 5. The live of Yerkes and Dodson[27], a publication with a long sleep and eventually high impact.

This article describes how mice were trained to pass through a white door instead of a black door by delivering an electric shock to them if they chose wrongly. The authors reported a bell-shaped curve in their study, which illustrated that the performance of mice increased with physiological or psychological arousal, but declined if the arousal became too high. This article had an average citation per year of 0.97 in the first 59 years, including the publication year and 58 years afterwards (deep sleep), and then an average citation per year of 1.9 in the subsequent 68 years (less deep sleep). After such sleep (68 years), however, the annual citations increased slightly for another 25 years and then increased sharply in last 16 years (Figure 5).

Conclusion

There were 387 classic articles in the WoS category of neurosciences, and all of them were in English. The *Journal of Physiology–London*, *Journal of Neuroscience* and *NeuroImage* were the three most productive journals. The US, UK and Canada were the major contributors. Thirteen institutions published ten or more classic articles each, and ten of these institutions are located in the US. Harvard University ranked top in terms of the number of classic articles published. Stanford University ranked top for three indicators namely first-author, corresponding-author and single-author articles. Seven authors of classic articles in neurosciences have won Nobel Prize in Physics, and Physiology or Medicine. K. J. Friston was the most prolific author in terms of classic articles in neurosciences. One sleeping beauty was published more than a century ago. The classic articles with highest citations in 2016 mostly introduced tools for subject assessment and data processing, showing that the neuroscience community is willing to share its research methods with others.

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