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## Neurological research in Europe, as assessed with a four-year overview of neurological science international journals

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■ **Abstract** This paper analyses all the peer-reviewed articles published by European authors in 161 neurological journals screened by ISI in accordance with Current Contents/Life Science and Current Contents/Clinical Medicine in the period 1995–1998. Our aim was to report the amount and quality of neurological research in the different countries of the European Union (EU), the USA and the world. The number of papers, the impact factors (IF), the population of the source country and gross domestic product (GDP), were downloaded. Data show that in the EU there is a progressive increase in the number of published papers from 1995 to 1998 and that large countries such as Germany, the United Kingdom, France and Italy rank at the top four places for absolute number of papers. The gap in the number of papers between

the USA and the EU significantly diminished in the examined period, from a difference of 14% to 6%. However, when the IF is considered, the USA performed better than EU, although excellent results have been obtained by the United Kingdom, Ireland, Netherlands and Sweden. When the number and quality of papers are plotted against the number of inhabitants or GDP, Sweden, the Netherlands and Finland are the leading countries in Europe. The present study demonstrates that neurological research in the EU is active and productive, is steadily increasing and is now a relevant part of all biomedical world research.

■ **Key words** Neurology · Bibliometrics · Scientific production · Europe · [www.Cilnews.unige.it](http://www.Cilnews.unige.it)

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### Introduction

Neurological diseases are common disorders with a lifetime prevalence of at least 6% of the general population [1], are often disabling, profoundly influencing the quality of life of the affected persons and their relatives, and have usually a long duration. Further, only symptomatic treatment, which is in many cases highly costly and of partial and modest efficacy, is now available. Moreover, the older population is increasing worldwide in size, and usually bears more neurological pathologies than the

younger one, thus leading to increasing social problems and cost burdens.

Significant advances have been made in recent years but it is manifest that a major part of the work has still to be done in order to improve our knowledge of the pathophysiology of these diseases and possibly to identify new therapeutic strategies.

In this light, it could be of interest to evaluate the neurological scientific activities in the European Union (EU), the USA and the world in recent years. This should be of importance in highlighting the actual weight of neurological research among the whole of global bio-

medical research, thus supporting an increase of EU funding in this strategically important medical field and to distribute the very limited resources to the more active and dedicated groups that have shown scientific excellence in their field of research.

Substantial research funding is now dispensed more on an international basis by the European Union (EU) and the knowledge of the scientific output of the different countries would be of help both for the European Scientific Committee for the adequate allocation and distribution of resources and for the scientific community of the different countries in order to identify the strategies for improving the quality of their research. The assessment of research output has therefore become a priority issue for the scientific research community [2, 3].

The evaluation and quantification of the results of research in a particular biomedical field is not however an easy task; the problem is still debated worldwide and there are indeed various limitations and errors in the different methods used [4–6].

Recently the Cilnews Group of the University of Genoa [www.cilnews.unige.it] has, however, developed reliable bibliometric techniques, widely accepted by the scientific community, which can assess with considerable precision the scientific production in a particular biomedical field on a national or international basis [7]. We performed a study of the neurological research output of the countries of the EU, the USA and the world in the years 1995–1998 analysing 161 neurological journals listed by the Institute for Scientific Information (ISI) and correlating them with bibliometric measures, i.e. impact factor (IF), and socio-economic variables, i.e. the source country population and its gross domestic product (GDP) [8].

## Methods

We considered all peer-reviewed articles, including editorials, reviews, technical notes and letters to the editors published in 161 journals of neurology and neuroscience screened by the ISI in accordance with Current Contents/Life Science and Current Contents/Clinical Medicine. The complete list of covered journals is shown in Table 1 and can be also found at www.cilnews.unige.it. Bibliographic data were downloaded from 1995, 1996, 1997 and 1998. A few of the 161 journals have been listed by ISI only for one or two years of the examined period and in this case only those years have been evaluated. Journal supplements containing reports of meeting or abstracts of congresses were excluded.

The country of the corresponding author was considered as the country of origin of the article.

For the purpose of this study, the definition of EU includes the 15 countries belonging to the EU plus Norway, because it is included in the European Economic area (EEA) and in all calculation concerning the EU carried out by the Statistical Office of the European Communities (Eurostat).

The papers from England, Scotland, Northern Ireland and Wales were grouped under the United Kingdom. The country of origin of 3% of the articles, mainly unsigned editorials, remained unknown because of lack of specific data.

The scientific weight of a paper was assumed to be the Impact Factor of the given nominal publication year of the international journal where it had been published, the Impact Factor being the average number of times articles published in a specific journal in the two previous years were cited in a particular year [9].

The resident population and GDP expressed in current billion US dollars for 1995, 1996, 1997 and 1998 were retrieved for each country from the Eurostat annual statistic reviews [10].

Like other works dealing with economical items, no statistical methods were applied to our data in order to compare the scientific production of the different countries, the aim of the present work being only to report and describe data and trend of the scientific production of the various European countries, which necessarily differ for numerous and complex historical, political and socio-economical reasons [7].

## Results

### ■ Number of papers

In the period 1995, 1996, 1997 and 1998 an overall number of 30 357 papers have been published in the EU neurological literature (Table 2). All EU countries were represented. The leading countries were Germany (23.8% of papers), the United Kingdom (21.6%), France (14.3%) and Italy (12.3%). For comparison, a total of 33 449 papers have been published in the same period in the USA. Europe accounts for 36% and the USA for 39.6% of all the world neurological literature of the same period. In 1995 the USA published 1079 neurological papers more than Europe but this difference progressively shortened during the following years and in 1998 the gap between the USA and Europe was reduced to 535 hits. In the four years examined the amount of neurological papers published in the different EU countries as compared to the total number of papers published in Europe slightly changed, with a relevant increase for Germany and Italy. Germany published in 1998 30% more papers than in 1995, Italian neurological production increased in the same period of 25%, and in France and the United Kingdom of 16%. In general, all EU countries increased their neurological output in the examined years. Neurological papers accounted in Europe for 5.9% of the total number of medical articles and 6.6% in USA. The ratio of neurological papers to all medical literature was highest in Germany (7.7%), Italy and Portugal (7.2 and 7.1%), Sweden and Finland (6.6%). In France it was 5.7% and in the United Kingdom 4.8%.

### ■ Quality of papers

The mean impact factor (IF) of papers from EU in neurological journals was 2.7 (Table 2). The world IF for neurological journals was 3 and respectively 3.6 was the IF of the USA. Among the EU nations, the United Kingdom and Ireland ranked first (3.3), followed by the

**Table 1** List of the neurological periodicals considered in the period 1995–1998

Acta Neurobiologiae Experimentalis	Experimental Brain Research	Neurobiology of Disease
Acta Neurochirurg	Experimental Neurology	Neurochirurgie
Acta Neurologica Belgica	Fortschritte der Neurologie Psychiatrie	Neurodegeneration
Acta Neurologica Scandinavica	Glia	Neuroepidemiology
Acta Neuropathologica	Headache	Neurologic Clinics
Aggressive Behavior	Hearing Research	Neurologica Research
Alzheimers Reports	Hippocampus	Neurology
Aktuelle Neurologie	Human Brain Mapping	Neuromuscular Disorders
American Journal of Neuroradiology	Journal of Neural Transmission	Neuron
Annals of Neurology	Invertebrate Neurosciences	Neuropediatrics
Annual Review of Neuroscience	Italian Journal of Neurological Sciences	Neurophysiologie Clinique–Clinical Neurophysiology
Annual Review of Psychology	Japanese Journal of Psychiatry and Neurology	Neuropsychiatry Neuropsychology and Behavioral Neurology
Aphasiology	Journal of Affective Disorders	Neuropsychobiology
Archives of Neurology	Journal of Child Neurology	Neuropsychologia
Baillieres Clinical Neurology	Journal of Clinical Neuroscience	Neuroradiology
Behavioral Neuroscience	Journal of Clinical and Experimental Neuropsychology	Neuroreport
Behavioral and Brain Sciences	Journal of Clinical Neurophysiology	Neuroscience
Behavioural Brain Research	Journal of Cognitive Neuroscience	Neuroscience Letters
Behavioural Processes	Journal of Comparative Neurology	Neuroscience Research
Brain	Journal of Comparative Physiology A-Sensory Neural and Behavioral Physiology	Neuroscience Research Communications
Brain Injury	Journal of Epilepsy	Neuroscience and Biobehavioral Reviews
Brain Research	Journal of Musculoskeletal Pain	Neurosurgery
Brain Research Bulletin	Journal of Nervous and Mental Disease	Neurosurgery Clinics of North America
Brain Research Reviews	Journal of Neural Transmission – Parkinsons Disease and Dementia Section	Neurosurgical Review
Brain Topography	Journal of Neural Transmission-Supplement	Pain
Brain and Cognition	Journal of Neurobiology	Paraplegia
Brain and Language	Journal of Neurology	Pediatric Neurology
British Journal of Medical Psychology	Journal of Neurology Neurosurgery and Psychiatry	Pediatric Neurosurgery
British Journal of Neurosurgery	Journal of Neuropsychiatry and Clinical Neurosciences	Physiological Chemistry and Physics and Medical NMR
Cephalgia	Journal of Neuroradiology	Physiological Research
Cerebrovascular and Brain Metabolism Reviews	Journal of Neuroscience	Progress in Neurobiology
Chemical Senses	Journal of Neuroscience Methods	Psychiatry and Clinical Neurosciences
Childs Nervous System	Journal of Neuroscience Research	Psychobiology
Clinical Autonomic Research	Journal of Neurosurgery	Psychological Bulletin
Clinical Electroencephalography	Journal of Neurotrauma	Psychological Review
Clinical Journal of Pain	Journal of Neurovirology	Psychosomatics
Clinical Neurology and Neurosurgery	Journal of the Autonomic Nervous System	Psychotherapy and Psychosomatics
Clinical Neuroscience	Journal of the International Neuropsychological Society	Restorative Neurology and Neuroscience
Cognitive Brain Research	Journal of the Neurological Sciences	Revue Neurologique
Cortex	Journal of the Peripheral Nervous System	Schizophrenia Bulletin
Critical Reviews in Neurobiology	Klinische Neurophysiologie	Schizophrenia Research
Current Opinion in Neurology	Learning & Memory	Seminars in Neurology
Dementia	Mental Retardation and Developmental Disabilities Research Reviews	Skull Base Surgery
Dementia and Geriatric Cognitive Disorders	Minimally Invasive Neurosurgery	Seizure
EEG-EMG-Zeitschrift für Elektroenzephalographie Elektromyographie und Verwandte Gebiete	Molecular Brain Research	Seizure-European Journal of Epilepsy
Electroencephalography and Clinical Neurophysiology	Molecular Neurobiology	Seminars in Neuroscience
Electromyography and Motor Control-Electroencephalography and Clinical Neurophysiology	Movement Disorders	Sleep
Epilepsia	Multiple Sclerosis	Somatosensory and Motor Research
Epilepsy Research	Muscle & Nerve	Stroke in the Elderly
European Archives of Psychiatry and Clinical Neuroscience	Nature Neuroscience	Synapse
European Journal of Neurology	Nervenarzt	Trends in Neurosciences
European Journal of Neuroscience	Nervenheilkunde	Vision Research
European Neurology	Neurobiology of Aging	Visual Neuroscience
Evoked Potentials-Electroencephalography and Clinical Neurophysiology		Zeitschrift für Psychosomatische Medizin und Psychoanalyse

Netherlands (2.9) and Sweden (2.7). The mean IF of the neurological literature in France was 2.6, in Germany 2.4 and in Italy 2.3. In general, in the countries of the EU, the IFs of neurological and of all biomedical fields were sim-

ilar. The quality of the published papers in the different countries remained almost unchanged during the four-year-period 1995–1998, with a continuous increase for France and Italy.

**Table 2** Scientific production of the different countries of the EU, the USA, and the world

State	Hits Number				Hits Percent Europe				Hits Percent All Fields				Mean IF			
	1995	1996	1997	1998	1995	1996	1997	1998	1995	1996	1997	1998	1995	1996	1997	1998
Austria	111	160	149	166	1,7	2,1	1,9	2,0	5,1	6,0	5,1	5,5	1,8	2,2	1,9	2,3
Belgium	175	186	197	219	2,7	2,4	2,6	2,6	5,2	4,9	5,2	5,5	2,2	1,8	1,9	2,3
Denmark	126	154	136	148	1,9	2,0	1,8	1,8	4,4	5,1	4,5	4,7	2,5	2,4	2,0	2,2
Finland	175	204	197	202	2,7	2,6	2,6	2,4	6,5	6,9	6,4	6,8	2,5	2,5	2,6	2,7
France	986	1054	1118	1169	15,0	13,7	14,5	14,0	5,7	5,5	5,9	6,0	2,5	2,6	2,6	2,8
Germany	1499	1800	1810	2147	22,8	23,3	23,5	25,7	7,4	7,5	7,5	8,4	2,4	2,4	2,4	2,5
Greece	23	54	24	41	0,3	0,7	0,3	0,5	2,3	4,4	1,8	2,7	2,1	1,8	1,5	1,7
Ireland	24	20	45	36	0,4	0,3	0,6	0,4	2,9	2,0	4,3	3,6	3,9	2,7	3,1	3,5
Italy	768	996	957	1020	11,7	12,9	12,4	12,2	6,8	7,4	7,3	7,5	2,1	2,2	2,4	2,5
Luxembourg	2	3	4	2	0,0	0,0	0,1	0,0	13,3	11,5	12,1	6,3	1,2	4,6	1,0	1,1
Netherlands	394	457	464	499	6,0	5,9	6,0	6,0	5,2	5,6	5,7	6,0	3,1	2,7	2,7	3,0
Norway	78	70	92	97	1,2	0,9	1,2	1,2	4,7	4,2	5,5	5,7	3,0	2,3	2,2	3,2
Portugal	35	35	29	35	0,5	0,5	0,4	0,4	9,0	7,4	5,3	6,6	2,3	2,3	2,0	3,3
Spain	280	397	357	415	4,3	5,1	4,6	5,0	4,3	4,9	4,3	4,7	2,9	2,8	2,6	2,9
Sweden	427	433	470	424	6,5	5,6	6,1	5,1	6,8	6,5	6,9	6,2	3,0	2,5	2,6	3,0
United Kingdom	1481	1692	1639	1750	22,5	21,9	21,3	20,9	4,6	4,9	4,9	5,1	3,4	3,2	3,2	3,4
European Union	6584	7715	7688	8370	100,0	100,0	100,0	100,0	5,7	5,9	5,9	6,2	2,7	2,6	2,6	2,8
USA	7663	8449	8432	8905					6,5	6,5	6,6	6,9	3,7	3,6	3,5	3,6
World	18318	21425	21469	23078					5,9	6,1	6,1	6,4	3,1	3,0	2,9	3,0

### ■ Scientific production vs population and GDP

The ratio between number of neurological papers and country population in millions of inhabitants was 20.4 for the EU and 32 for the USA (Table 3). Similarly to other medical fields small countries performed better. The leading country was Sweden (50), followed by Finland (38.5), the Netherlands (29.6), the United Kingdom (28) and Denmark (27). If we calculate the ratio between the number of neurological papers and GDP, the mean value for the EU was 0.97 and 1.25 for the USA. In countries of South Europe the value dropped to 0.4–0.8. Sweden (2), Finland (1.9), the United Kingdom (1.5) and Netherlands (1.4) had the highest scores.

### Discussion

We are aware that the method we used has several limitations, for example it does not take into account papers dealing with neurological science but published in international journals that are not quoted as of prevalent neurological interest. So that many valuable papers coming from high level neurological laboratories were not taken into account, despite the fact that they were published in prestigious journals, say New England Journal of Medicine, the Lancet or others. However, the present method account for simplicity, it is easy repeatable, and only 3% out of all papers of interest were discharged due to lack of address. On the other hand, watching for institutions in address is troublesome and provides a tenfold larger experimental error. Moreover, it seems reasonable to infer that a paper published on

**Table 3** Papers published in each EU Country, the USA and the world according to inhabitants and GDP

State	Hits per Inhabitants				Hits per GDP			
	1995	1996	1997	1998	1995	1996	1997	1998
Austria	13,8	20,0	18,6	20,6	0,6	0,9	0,7	0,7
Belgium	17,5	18,6	19,4	21,6	0,8	0,9	0,8	0,8
Denmark	24,5	29,9	26,1	28,1	0,9	1,1	0,9	0,8
Finland	35,0	40,8	38,8	39,4	1,8	2,2	2,1	1,6
France	17,4	18,6	19,7	20,6	0,8	0,8	0,8	0,9
Germany	18,4	22,1	22,2	26,2	0,8	0,9	0,9	0,9
Greece	2,2	5,3	2,3	3,9	0,3	0,7	0,3	0,3
Ireland	6,8	5,7	12,8	9,9	0,5	0,5	0,9	0,5
Italy	13,4	17,4	16,7	17,8	0,7	0,8	0,8	0,8
Luxembourg	5,2	7,8	10,4	4,8	0,1	0,2	0,3	0,1
Netherlands	26,0	30,2	30,2	32,2	1,3	1,5	1,4	1,3
Norway	18,1	16,3	21,2	22,1	0,7	0,6	0,8	0,6
Portugal	3,6	3,6	2,9	3,5	0,5	0,5	0,3	0,3
Spain	7,2	10,2	9,2	10,6	0,5	0,8	0,7	0,7
Sweden	49,1	49,8	53,3	47,9	2,0	2,0	2,3	1,7
United Kingdom	25,5	29,1	28,1	29,8	1,4	1,6	1,5	1,5
European Union	17,7	20,7	20,6	22,3	0,9	1,0	1,0	1,0
USA	29,4	32,4	32,4	33,6	1,2	1,3	1,3	1,2
World	3,7	4,3	4,1	4,0	0,8	0,9	0,8	0,8

HITS = papers and letters; IF = impact factor; inhabitants = million inhabitants; GDP = billion US\$ of gross domestic product; MEAN IF = (sum of IFs of hits)/(number of hits); HITS % EUROPE = 100\* (hits of the country of interest)/(sum of hits of European Union).

multidisciplinary journals are usually sustained by numerous previous paper published in specific journals.

Moreover, we are aware that sometimes authors coming from different countries have written an article that our method attributes only to the state of corresponding

author. However, it seems reasonable to infer that during international collaborations, relative papers will be written by all the coworkers, at least when a rather long period is taken into account.

Similarly, we know that Impact Factor is a highly debated bibliometric index, accounting for a mean citation index [11]. Some people claim that the number of citations a given paper reaches might be a more appropriate index [12]. However, IF can be calculated within few years (two), so that recent indexes are always available. On the contrary, the total citations should be calculated over a rather long time interval, say ten or more years. Moreover, the number of times a given article was cited does not automatically mean that such a paper will sustain a scientific value over the time. As a paramount example, one could consider that the more important Einstein's papers were almost unquoted for about twenty years following their publication. Indeed, IF deals not with the real scientific quality of a paper, but with its audience. Therefore, our method assesses volume and compliance of scientific publications, rather than their true value.

Lastly, notice that this kind of study handles several thousands of papers and deals with macroeconomic problems, so that average indexes are fully justified.

In the examined years, 1995–1998, all EU countries published papers in the neurological field. Large countries, such as Germany, the United Kingdom, France and Italy ranked at the top four places for absolute number of papers. The amount of papers published in Neurology by European countries is only slightly lower than that of the USA, in spite of the different amount of resources dedicated to neuroscience research in USA and in Europe. It is relevant to note that in Europe there was a progressive increase in the number of published papers from 1995 to 1998, passing from 6584 to 8370 hits, which is indeed a relevant increase of 21% in the absolute number of papers. In the same period also in the USA there was an increase of papers and letters published in peer reviewed journals but the increase was only of 14%. Therefore in the four years examined the gap between the USA and Europe is diminished passing from a difference of 14% to a difference of 6%, thus confirming that now EU countries have a leading role in world neurological literature. However, when other variables such as the quality of papers determined with the evaluation of IF are considered, ranking changes considerably, and USA performed better than Europe (3.6 vs 2.7 in 1998). IF, the average number of times the articles published in a specific journal in the two previous years are cited in a particular year, has several drawbacks but in general can be considered a fair indicator of the scientific quality of a paper. In Europe, the United Kingdom, Ireland, the Netherlands and Sweden excelled for their mean IF, while Germany, France and Italy had a lower IF, slightly inferior to the mean IF of all the neurological papers published in the period 1995–1998 in the EU.

Numerous are the reasons of this result, but probably the most important is that journals with the largest audience are published in countries of English language and therefore the bibliometric analysis is biased toward English language journals. Authors of other countries, such as Germany, France and Italy had in the past a strong tradition to publish in their native language and nowadays may have more difficulties to publish their papers in journals of great international competition with referees of native English language. However it must be considered that English is now the universal scientific language and in the future bibliometric analysis will be done only considering journals of this language.

When the number and quality of papers are plotted against the number of inhabitants or the gross domestic product (GPD), small countries had a higher scientific output. Sweden, Finland, the Netherlands excelled for the number of published neurological papers for millions of inhabitants, while for the ratio between scientific publications and GPD, Sweden, Finland and the Netherlands were again at the top of all the EU countries. These findings for the neurological research are in agreement with the data obtained for all the other biomedical areas [5]. A possible explanation of this result is that in small countries of north Europe the resources are better distributed and a higher percentage of the GPD is assigned to scientific research. However from the present study it is not possible to make any relationship between resources invested in research and scientific production. In fact the ratios between a produced item and the country population and/or its gross domestic product are typical indexes that concern with the compliance, popularity and/or diffusion of these items among the given population: e. g., the diffusion of cars, fountain pens, crimes events. These indexes do not concern with neither surrogate the specific cost of the item of interest. In our case, these ratios estimate diffusion and economic consensus. The ratio between hits and gross domestic research and development expenditure (GERD) and R&D personnel cannot be calculated, as also Eurostat itself claims [10].

In this study we considered only journals quoted as neurological journals by ISI. This method has some drawbacks and does not cover all the neurological production of the period 1995–1998. In fact neurologists do not necessarily publish their papers in neurological journals but can send their results to journals of other fields, which specifically address their area of interest. The identification of neurological papers in other journals is complicated and was not attempted in this study. We are now developing new methods to identify the scientific background of the authors, matching keywords, names of the authors and Institution of provenance.

In conclusion, the present study gives a fairly complete and reliable overview of the neurological research in Europe in the years 1995–1998. In the EU the neuro-

logical research is active and productive, and accounts for 5.9% of all the biomedical fields. For a determined country, to precisely know its position in comparison with its competitors can be utilized to identify the strategies to improve the property of distribution of re-

sources and therefore to ameliorate the quality of its research.

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