Research output on lucid dreaming research from 1966 to 2019: Bibliometric and network analyses on lucid dreaming

Daniele Pepe

Laboratory for Disease Mechanisms in Cancer, KU Leuven, Leuven, Belgium

Summary. Lucid dreaming is a phenomenon that can be classified as altered state of consciousness. In the last years the scientific interest for it has grown exponentially. To understand how the research on this topic evolved during the time, bibliometric and network analyses were performed. The focus of the analysis was on: 1) papers; 2) authors; 3) countries and 4) collaborations. Scopus database was used to retrieve articles on lucid dreaming. The analyses included publications published between 1966 and 2019. The productive countries, citation analysis, keywords co-occurences, international collaboration, active authors, and active journals were retrieved and analyzed. A total of 306 articles were retrieved. They refer to the period between 1966 to 2019. The average citations per documents was 12.79. The documents annual growth rate was 5.60. Stratified by number of publications, the United States ranked first with 59 papers. The highest percentage of international collaboration was seen for researchers from Germany. Most active journals in the context of lucid dreaming were Dreaming, International Journal of Dream Research, Perceptual and Motor Skills. Schredl M. and Erlacher D. were the two most productive authors in terms of number of published papers, number of citations, h and g indices. LaBerge S. was the author with the longest research productivity. The strongest co-authorship relationship was between Schredl M. and Erlacher D while the strongest university collaboration was between Heidelberg University (Germany), Central Institute of Mental Health (Germany) and the University of Bern (Switzerland). Publications on lucid dreaming have increased in the past decades. This shows that the topic is becoming more and more appealing to the scientific world and not anymore confined to the esoteric tradition. Several countries are involved in the research and some of them collaborate on this topic. The number of papers is exponentially increasing from 1979. This means that the topic is a hot topic and more and more studies are expected in the next years for a better understanding of a branch of consciousness that was mainly overlooked until 1979.

Keywords: lucid dreaming; research output; bibliometric analyses; network analyses

1. Introduction

Translating Lucid dreaming is a state where one becomes aware that he or she is dreaming while remaining physiologically asleep. This state is scientifically and objectively verifiable. Infact, scientific experiments demonstrated that participants during the REM sleep can produce volitional eye movements that can be recorded in the electrooculogram (LaBerge, Nagel, Dement & Zarcone, 1981). A dream to be classified as lucid dream needs that the subject is aware of dreaming while dreamings. There are however other scientists that proposed more complex criteria to classify a dream as lucid dream. This means that some dreams can be more lucid than other (Barrett, 1992; Moss, 1986). Regarding the physiology of the lucid dreaming state, it is associated with a high level of automatic nervous system and a higher H-reflex suppression (LaBerge, Levitan & Dement, 1986; Brylowski, Levitan & LaBerge, 1989). Recently a study suggested that the activity of lucid dreaming could be associated to an increased functional connectivity between the anterior prefrontal cortex and temporoparietal association areas. Normally those regions are deactivated during sleep (Baird, Castelnovo, Gosseries & Tononi, 2018). The phenomenon of lucid dreaming occurs mainly in the REM phase, a state where the skeletal muscles of the body are suppressed with the only exception of eye movements that allowed proving scientifically the validity of the lucid dreaming (LaBerge, Nagel, Dement & Zarcone, 1981). There are different techniques to induce the lucid dreaming state. A review (Stumbrys, Erlacher, Schädlich & Schredl, 2012) divided them in three different categories: 1) cognitive techniques, based on the development of personal skills as intention, suggestion, self-hypnosis, hypnagogic techniques; 2) external stimulation during the REM sleep; 3) other techniques that are not covered from the previous two.

Lucid dreaming is part of a wider range of states defined as altered state of consciousness (ASC). Blackmore (Blackmore, 1988) tried to explain several ASCs as lucid dreams, false awakenings and out-of-body experiences (OBE) proposing a unified theory. Those phenomena are the result of a normal modeling process of the reality not input-driven. In other words, when there are situations as accidents, acute stress, sensory deprivation a participant could be deprived of common information useful to build a normal model of reality. In these situations to maintain a model of self in the world, alternatives models can be built that can justify for

Corresponding address:
Daniele Pepe, Laboratory for Disease Mechanisms in Cancer, KU Leuven, Leuven, Belgium.
Email: danielepepe84@gmail.com

Submitted for publication: March 2020
Accepted for publication: June 2020
DOI: 10.11588/ijodr.2020.2.72226

example the OBE or lucid dreams. An important difference between the two states concerns the awareness about the environment. In a lucid dream the subjects are aware that the environment where the dream takes place is not real instead in OBEs the subjects assume that the surroundings are real (Blackmore, 1988). In this paper, bibliometric and network analyses were performed to understand how the scientific research on lucid dreaming is evolved. The number of publications on lucid dreaming is exponentially increasing during the years, as showed in this paper. Understanding the research patterns about lucid dreaming becomes therefore important to have an idea about what it was done and what to expect in the future in terms of collaborations, number and type of papers and type of journals where the papers will be published. Furthermore, bibliometric analyses allows to characterize and to detect potential weak points in the research activities in a way to help in addressing future research lines. Four different aspects were considered: 1) papers; 2) countries 3) authors and 4) collaborations. This comprehensive analysis represents an effort to discover the fundamental papers, sources, authors and collaborations that have so far characterized the research on lucid dreaming.

2. Methods

The methods used in this paper have been previously descrived in bibliometric studies (Zyoud et al., 2015; Sweileh et al., 2015; Sweileh et al., 2016a; Sweileh et al., 2016b). The Scopus database was used as it contains a larger number of journals than either Pubmed or Web of Science and it permits more accurate data analyses compared to Pubmed or Google Scholar (Bakkalbasi, Bauer, Glover & Wang, 2006; Falagas, Pitsouni, Malietzis & Pappas, 2008). The query was based on three keywords "Lucid dreaming" OR "Lucid dreams" OR "conscious dreaming". The search was done on article title, abstract and keywords. The quality of the results was tested manually by reviewing the retrieved publications. Concerning the contribution of the countries in the research topics two types of articles are possible: the single country publications (SCP) where all authors belong to the same country and this can be used to measure the intra-country collaboration; and multiple country publications (MCP) in which authors belong to different countries and can measure the level of international collaboration.

To evaluate the quality of research (for authors and sources) several type of measures were used: the Hirsch-index (h-index), percentage of highly cited articles (Hirsch, 2005); the m-index and the g-index (Egghe, 2006). The h-index is an index based on the number of citations associated to the scientific papers of one author or one journal. It is computed as follow: for each publication, the corresponding number of citations is computed. Then, the citations for each paper are sorted from the largest to the lowest value. The last position where the number of citations is greater or equal to the position is defined the h-index. For example, let's assume a researcher has 4 articles A1, A2, A3, A4. The corresponding number of citations is 12, 9, 8, 2. Each number occupies a position (12 the first, 9 the second and so on). The h-index is 3, i.e.the last position where the number of citations is greater than the position. The m-index takes in consideration the date of an academic's career. It is defined as the h-index divided by the number of years since the first published paper of a scientist or journal. The g-index can be computed ordering a set of articles according to their number of citations in a decreasing order and taking the unique largest number of articles g in a way that the top g articles received at least g2 citations. In other words, if an author or a journal has a g index of 10 means that there are ten articles with at least 100 citations.

The h-index and the m-index were obtained from Scopus database. The Lotka's law and the annual growth rate were also computed. The Lotka's law (Lotka, 1926) states that a small number of scientists are responsible for the most of contributions produced from the complete scientific community. This law can be explained from the following formula:

$$Y = C / X^{\beta}$$

where **Y** is the number of authors, **X** the number of contributions, C is a constant depending from the scientific field and **β** that have a recurrent statistically value the is approximately equal to 2.

Lotka's law assumption implies a theoretical beta coefficient of Lotka's law equal to 2. The Kolmogorov-Smirnoff two sample test was applied to verify if there are differences between the observed and the theoretical Lotka distributions. The collaboration index (CI) is the mean number of authors per joint paper (Elango & Rajendran, 2012). Single authored papers are not considered in this analysis as the CI would be always 1. The formula to compute CI is:

CI = Total authors/Total joint papers

Another important index is the Authors per Document index. It is computed using the following formula:

Authors per Document = Number of documents/number of authors

The Co-Authors per document index is calculated as :

Co-authors per document = average number of co-authors/number of documents

Authors per document is always equal or greater than Co-authors per document as in the first one is is evaluated the author appearances while in the second one is counted only one.

Authorship and university collaborations were analyzed by a network analysis (Kumar & Kumar, 2008; Batagelj & Cerinšek, 2013). A bipartite network A was created. It is a rectangular binary matrix where the rows represent the authors or universities and the columns the papers. The cell A contains the value 1 if the author/university m is associated to the paper n, otherwise 0. Further, I proceeded to the coupling operation. Starting from the network A a coupling is performed in the following way:

$$B = A * A^{T}$$

The matrix B now is a square and symmetrical matrix where the rows and columns are the authors/universities. A cell $B_{q,r}$ contains a value representing the number of papers shared between the author/university q and the author/university r.

The matrix was converted in the corresponding weighted graph where the connections between two nodes (i.e. the authors/universities) represent the number of shared papers

Table 1. General description on the 299 documents.

Description	Results
Documents	299
Sources (Journals, Books, etc.)	136
Keywords Plus (ID)	1045
Author's Keywords (DE)	668
Period	1966-2019
Average citations per document	12.79
Authors	507
Author Appearances	753
Authors of single-authored documents	91
Authors of multi-authored documents	416
Single-authored documents	116
Documents per Author	0.59
Authors per Document	1.7
Co-Authors per Documents	2.52
Collaboration Index	2.27

between the nodes. The conversion was performed by the R package *igraph*. The graph was visualized with Cytoscape [https://cytoscape.org/]. The R package "bibliometrix" (Aria & Cuccurullo, 2017) was used for performing the analyses reported in this paper.

3. Results

3.1. General description

A general description about the scientific works (see Table 1) reveals that the number of published articles in the period between 1966 and 2019 was 306. Seven works were removed because no information about authors was available. They were published in 136 different sources. Table 2

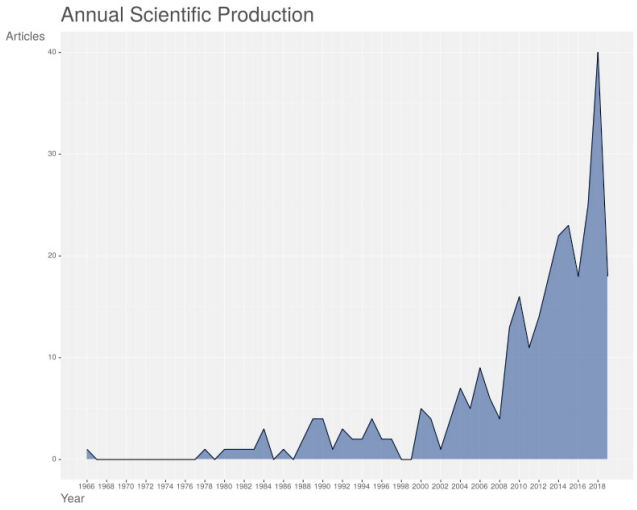

Figure 1. The evolution of the scientific production from 1966 to 2019.

Table 2. Distribution of the 299 documents based on the document type

Document types	Number
Article	219
Book	5
Book chapter	21
Conference paper	9
Editorial	3
Erratum	2
Letter	1
Note	9
Review	29
Short Survey	1

shows that most of documents are articles (219/299, 73%) but also review are quite important (29/299, 9.7%). The number of authors is 507 and the number of documents per authors was about 0.6. The average number of co-authors per document was 2.52. The average number authors per document was 1.7. The average number of citations per document was 12.79.

The collaboration index was 2.27. It is interesting to note that there are 116 single-authored documents (about 39% of the documents) written by 91 authors.

The annual scientific production increases exponentially (see Figure 1). It is interesting to note that there are no published scientific documents between the years 1967 and 1978. Then from the 1980 the research on lucid dreaming has started to increase exponentially reaching the maximum on 2018. The number of papers published during the last year (2019) was 18.

3.2. Results on documents

The most cited papers are illustrated in the Table 3. In the

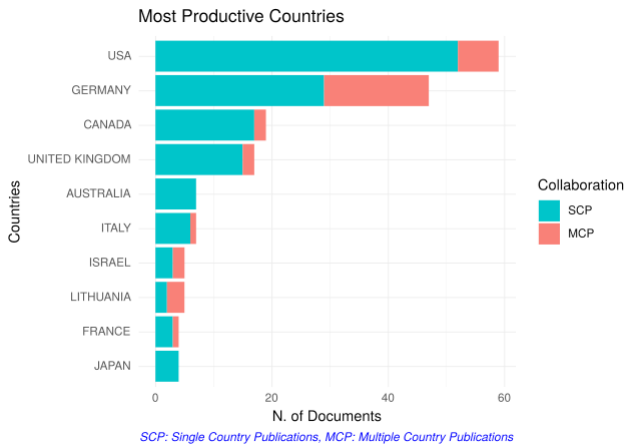

Figure 2. The barplot illustrated the number of scientific documents for the top 10 countries and the collaboration evaluation based on the SCP and MCP indeces.

Table 3. Most cited papers. It is reported the total number of citation per year (TC/Year) and the Impact factor of the journal.

Paper	TC	TC Year
Voss U, 2009, Sleep	213	17.75
Aurora RN, 2010, J Clin Sleep Med	158	14.36
Watson D, 2001, J Abnorm Psychol	151	7.55
Mahowald MW, 1991, Sleep	121	4.03
Takeuchi T, 1992, Sleep	109	3.76
Dresler M, 2012, Sleep	104	11.56
LaBerge SP, 1981, Percept Mot Skills	103	2.58
Schredl M, 2004, Pers Individ Differ	88	5.18
Spoormaker VI, 2006, Psy Psysom	86	5.73
Dresler M, 2011, Curr Biol	76	7.60

top ten papers, 4 were published in the *Sleep* journal. The highest cited paper was written by Voss U in 2009 and published in the journal *Sleep*. The oldest paper in the table is the paper published by LaBerge in 1981 and published in *Perceptual and Motor Skills*.

The top 10 journals based on the number of published papers on lucid dreaming are reported in Table 4. The sources with the highest number of published papers are *Dreaming* and *International Journal of Dream Research* (42 papers). The sources with the highest number of cited papers are *Sleep* and *Consciousness and Cognition* (685, 387). The journal with the highest h and g index was *Dreaming* while the highest based on the m-index was *Frontiers in Psychology*.

3.3. Results based on countries

The contribution of the scientific research at country level are reported in the Table 5 and Figure 2. The countries with the highest number of published papers were USA and Germany with 59 and 47 published papers respectively. Germany showed also the highest multiple country publications (18 papers) . The highest number of cited papers come from research groups in Germany with a total number of citations of 1123 and number of citations per paper of 23.89. The countries with the highest citations per article were Norway and Netherlands (44 and 42 respectively).

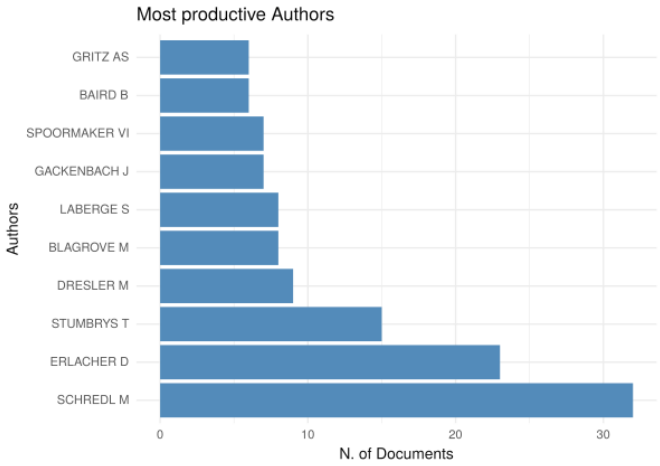

Figure 3. A barplot illustrating the top 10 most productive authors based on the number of published documents.

3.4. Results based on authors

The Lotka's law was evaluated. The estimated Beta coefficient was 1.74 and the p-value 0.85. This means that there are no differences between the theoretical and observed distributions. Therefore, also for research on lucid dreaming, few authors are responsible for most of papers published from the whole scientific community. The most productive authors are showed in Figure 3 and 4 as well as in Table 6. The two most relevant authors based on the number of published papers were Schredl M and Erlacher D. The authors have started to publish in 2003 and they are the most prolific authors of the last 15 years. In fact their scientific works were the most cited (582 and 457 citations respectively).

Table 4. Most relevant journals. Number of articles published on each journal (NP), total citations (TC) h, g and m indices are reported.

Source	h_index	g_index	m_index	TC	NP
Dreaming	11	16	0.44	331	42
International Journal of Dream Research	7	13	0.7	240	42
Perceptual and Motor Skills	7	14	0.175	249	14
Consciousness and Cognition	9	11	0.334	387	11
Frontiers in Psychology	7	9	0.875	89	11
Sleep	8	8	0.229	685	8
Personality and Individual Differences	7	7	0.226	277	7
Medical Hypotheses	3	5	0.09	31	5
Behavioral and Brain Sciences	2	4	0.095	49	4
Journal of Sleep Research	3	4	0.334	60	4

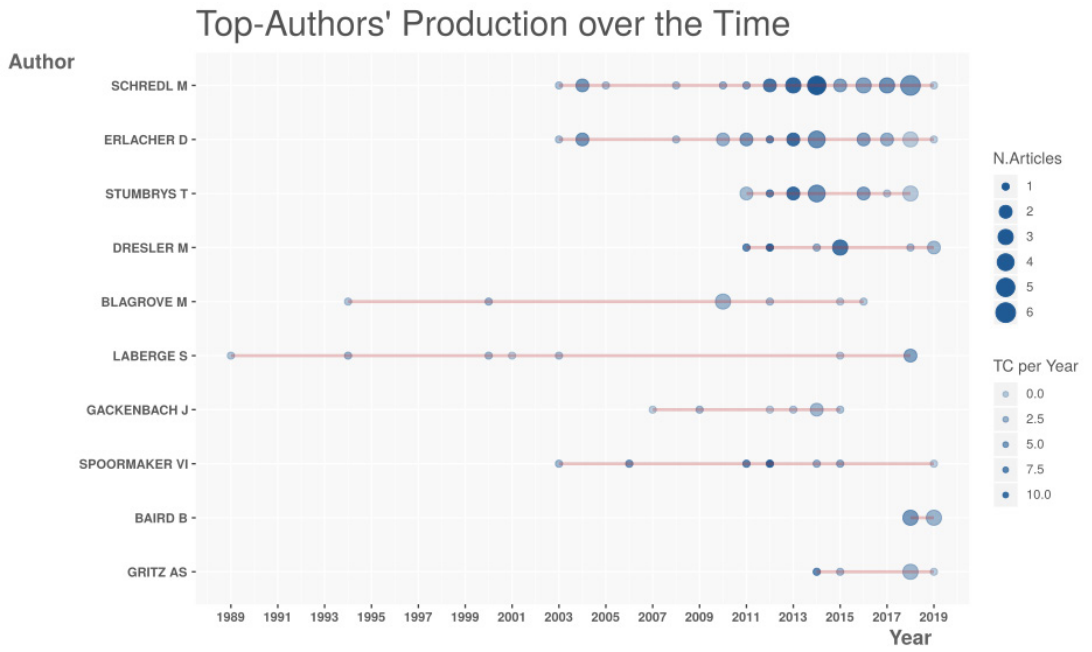

Figure 4. The figure illustrates the top 10 authors productivity over the time..

They showed also the highest h and g indeces. Instead, the authors with the highest m-index values were Baird B and Schredl M (1 and 0.778 respectively). The author with the longest productivity was LaBerge S. He started to publish in 1981 and his last researches were published in 2018.

3.5. Network analyses on authors and universities

The next analyses allowed to unveil the most relevant co-authorships and collaboration between universities or centers of research. After the coupling technique two networks were generated, the co-authors network and the universities network. The first one has 507 (number of authors) nodes and 1479 connections while the second has 317 nodes and 761 connections. A connection represents the presence of a shared paper. To each connection is associated a weight representing the number of shared papers. The following refinements were applied to the networks: a) only the connections with a weight greater than 2 (for the co-authorship analysis) or 1 (for the university collaboration analysis) were kept; b) self-loops were removed and c) nodes with zero connections were removed . This allowed to detect only the most important authors or university collaborations. The final co-authorship network contained 18 nodes and 26 connections (Figure 5) while the university collaboration network 22 nodes and 18 connections (Figure 7). The different edge thickness represents the number of shared papers between the authors where a thinner connection represents a limited number of shared papers. Vice versa a thicker connection represents a high number of shared papers. The connections weights go from a minimum of 3 to a max of 13 for the co-authorship network and from 3 to 10 for the university network. The co-authorship network revealed 5 different clusters. The cluster with more than 2 authors were constituted respectively by: 1) Schredl, Erlacher, Gritz, Rieger, Schdlich, Stumbrys; cluster 2) Spoormaker, Dresler, Wehrle, Steiger, Czisch, Holsboer. The strongest co-autorship was observed between Schredl M an Erlacher D. The university

Table 6. Evaluation of the most productive authors based on total citations, number of papers and h, g, and m indices.

Author	h_index	g_index	m_index	TC	NP	PY_start
Schredl M.	14	23	0.778	582	32	2003
Erlacher D.	11	21	0.611	457	23	2003
Stumbrys T.	7	15	0.7	242	15	2011
Dresler M.	6	9	0.6	266	9	2011
Blagrove M.	5	8	0.185	114	8	1994
LaBerge S.	5	8	0.156	158	8	1989
Gackenbach J.	4	7	0.286	50	7	2007
Spoormaker V.I.	6	7	0.333	347	7	2003
Baird B.	3	4	1	21	6	2018
Gritz A.S.	3	6	0.429	67	6	2014

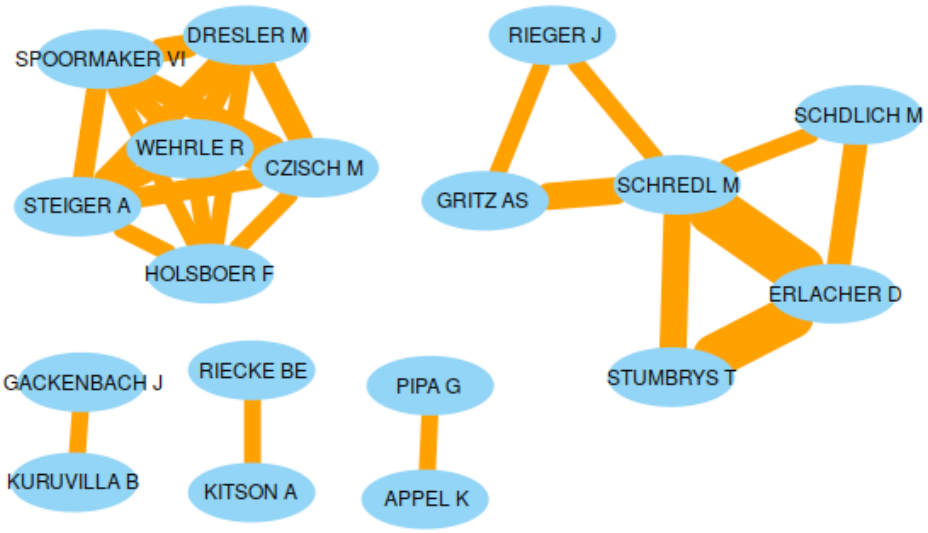

Figure 5. The co-authorship network analysis revealed the most important collaborations between authors.

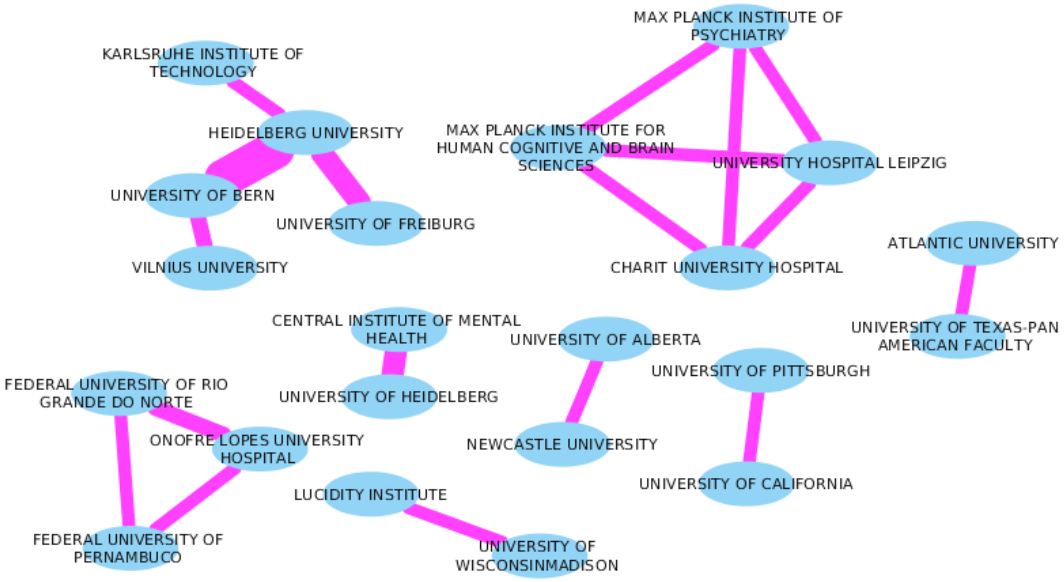

Figure 6. The most representative collaborations between universities in the context of lucid dreaming research.

network showed 8 different clusters where the most representative in terms of number of universities were: cluster1 constituted by Heidelberg University, Central Institute of Mental Health-Mannheim (Germany), University of Bern, University of Freiburg, Vilnius University and Karlsruhe Institute of Technology; cluster 2 represented by Max Planck Institute of Psychiatry, Max Plank Institute for Human Cognitive and Brain Scienses, University Hospital Leipzig and Charit University Hospital. Most of the Universities in the two clusters are German universities showing a strong intercountry collaboration between researchers working in German institutes. The strongest collaboration was observed between the Heidelberg university (Germany), Central Institute of Mental Health-Mannheim (Germany) and the University of Bern (Switzerland).

4. Discussion

This paper analyzed 299 valid papers on lucid dreaming retrieved in Scopus. The list of scientific works on lucid dreaming could be incomplete as only English works were considered and only the ones present in Scopus. However, this does not affect the general conclusions and patterns described in this paper. By bibliometric and network analyses, it was investigated how the research evolved from the first publication on the topic. In fact, the annual scientific production increased exponentially starting from 1981, although the first paper was published in 1966. Therefore, a lag phase of at least 15 years was necessary before the scientific communities have started getting interested in lucid dreaming. The main reason could have been the absence of a scientific approach to validate a lucid dreaming state until LaBerge et al. (1981) developed a method based on the vol-

untary movement of eyes during the REM phase. The first review on lucid dreaming appeared in 1989, 23 years after the first paper on lucid dreaming. Most of the reviews were published starting from 2010 (21 out 29). This means that only in the last years the amount of data on lucid dreaming has became such as to develop reviews, helpful to summarize different results on a topic. The high presence of single-author papers (39%) and the few researchers involved in a co-authorship are a clear indicator of the need to be more consistent in terms of joint scientific efforts. In fact, a recent review (Baird, Mota-Rolim & Dresler 2019) reported that most studies on lucid dreaming have relied on small sample sizes, which limits the generalizability of the findings, making the results often non-consistent. If more researchers would have been in lucid dreaming research, probably it would be possible to have studies with more subjects involved and therefore having more consistent results. The review reported that only one fMRI study contrasting lucid and non-lucid REM sleep was so far published. .

The same review affirms that additional studies based on larger sample sizes and application of technologies as MEG or concurrent EEG/fMRI would be relevant to have a better ideas about the neural activity during lucid dreaming. The analysis on Journals revealed that the most relevant ones are specialized journals as Dreaming or International Journal of Dream Research. This indicates that lucid dreaming is still a topic that needs to find relevant applications above all in the context of clinical implications (Baird, Mota-Rolim & Dresler 2019). In conclusion, this bibliometric study allowed to characterize the scientific research on lucid dreaming in terms of most relevant authors, papers, journals and collaboration. Also it allowed to detect also the current weak points as the limited number of researchers and limited clinical implications of lucid dreaming. However, considering the increasing number of papers and reviews published in the last years, new scenarios could emerge in the next years allowing to gain more insights in the world of lucid dreaming research.

References

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959-975.

Baird, B., Castelnovo, A., Gosseries, O., & Tononi, G. (2018). Frequent lucid dreaming associated with increased functional connectivity between frontopolar cortex and temporoparietal association areas. Scientific reports, 8(1), 17798.

Baird, B., Mota-Rolim, S. A., & Dresler, M. (2019). The cognitive neuroscience of lucid dreaming. Neuroscience & Biobehavioral Reviews, 100, 305-323.

Bakkalbasi, N., Bauer, K., Glover, J., & Wang, L. (2006). Three options for citation tracking: Google Scholar, Scopus and Web of Science. Biomedical digital libraries, 3(1), 7.

Barrett, D. (1992). Just how lucid are lucid dreams? Dreaming, 2(4), 221-228.

Batagelj, V., & Cerinšek, M. (2013). On bibliographic networks. Scientometrics, 96(3), 845-864.

Blackmore, S. (1988). A theory of lucid dreams and OBEs. In Conscious mind, sleeping brain (pp. 373-387). Springer, Boston, MA.

Brylowski, A., Levitan, L., & LaBerge, S. (1989). H-reflex suppression and autonomic activation during lucid REM sleep: a case study. Sleep, 12(4), 374-378.

Egghe, L. (2006). Theory and practise of the g-index. Scientometrics, 69(1), 131-152.

Elango, B., & Rajendran, P. (2012). Authorship trends and collaboration pattern in the marine sciences literature: a scientometric study. International Journal of Information Dissemination and Technology, 2(3), 166.

Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2008). Comparison of PubMed, Scopus, web of science, and Google scholar: strengths and weaknesses. The FASEB journal, 22(2), 338-342.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. Proceedings of the National academy of Sciences, 102(46), 16569-16572.

Kumar, S., & Kumar, S. (2008). Collaboration in research productivity in oil seed research institutes of India. In Proceedings of Fourth International Conference on Webometrics, Informetrics and Scientometrics (pp. 28-1).

LaBerge, S. P., Nagel, L. E., Dement, W. C. & Zarcone, V. P (1981). Lucid dreaming verified by volitional communication during REMsleep. Perceptual Motor Skills, 52, 727–732.

Lotka, A. J. (1926). The frequency distribution of scientific productivity. Journal of the Washington academy of sciences, 16(12), 317-323.

Moss, K. (1986). The dream lucidity continuum. Lucidity Letter, 5(2), 25-28.

LaBerge, S., Levitan, L., & Dement, W. (1986). Lucid dreaming: Physiological correlates of consciousness during REM sleep. Journal of Mind and Behavior, 7(2-3), 251-258.

Sweileh, W. M., Sa'ed, H. Z., Al-Jabi, S. W., & Sawalha, A. F. (2015). Contribution of Arab countries to breast cancer research: comparison with non-Arab Middle Eastern countries. BMC women's health, 15(1), 25.

Sweileh, W. M., Shraim, N. Y., Al-Jabi, S. W., Sawalha, A. F., Rahhal, B., Khayyat, R. A., & Sa'ed, H. Z. (2016a). Assessing worldwide research activity on probiotics in pediatrics using Scopus database: 1994–2014. World Allergy Organization Journal, 9(1), 25.

Sweileh, W. M., Shraim, N. Y., Sa'ed, H. Z., & Al-Jabi, S. W. (2016b). Worldwide research productivity on tramadol: a bibliometric analysis. Springerplus, 5(1), 1108.

Stumbrys, T., Erlacher, D., Schädlich, M., & Schredl, M. (2012). Induction of lucid dreams: A systematic review of evidence. Consciousness and Cognition, 21(3), 1456-1475.

Zink, N., & Pietrowsky, R. (2015). Theories of dreaming and lucid dreaming: An integrative review towards sleep, dreaming and consciousness. International Journal of Dream Research, 8(1), 35–53

Zyoud, S. H., Al-Jabi, S. W., Sweileh, W. M., & Waring, W. S. (2015). Scientific research related to calcium channel blockers poisoning: Bibliometric analysis in Scopus, 1968–2012. Human & experimental toxicology, 34(11), 1162-1170.

Voss, U., Holzmann, R., Tuin, I., & Hobson, A. J. (2009). Lucid dreaming: a state of consciousness with features of both waking and non-lucid dreaming. Sleep, 32(9), 1191-1200.