A comparison of 3 productive authors’ research domains based on sources from articles, cited references and citing articles using social network analysis

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Abstract
Background: An individual’s research domain (RD) can be determined from objective publication data (e.g., medical subject headings and Medical Subject Headings (MeSH) terms) by performing social network analysis. Bibliographic coupling (such as cocitation) is a similarity metric that relies on citation analysis to determine the similarity in RD between 2 articles. This study compared RD consistency between articles as well as their cited references and citing articles (ARCs).

Methods: A total of 1388 abstracts were downloaded from PubMed and authored by 3 productive authors. Based on the top 3 clusters in social network analysis, similarity in RD was observed by comparing their consistency using the major MeSH terms in author articles, cited references and citing articles (ARC). Impact beam plots with La indices were drawn and compared for each of the 3 authors.

Results: Sung-Ho Jang (South Korea), Chia-Hung Kao (Taiwan), and Chin-Hsiao Tseng (Taiwan) published 445, 780, and 163 articles, respectively. Dr Jang’s RD is physiology, and Dr Kao and Dr Tseng’s RDs are epidemiology. We confirmed the consistency of the RD terms by comparing the major MeSH terms in the ARC. Their La indexes were 5, 5, and 6, where a higher value indicates more extraordinary research achievement.

Conclusion: RD consistency was confirmed by comparing the main MeSH terms in ARC. The 3 approaches of RD determination (based on author articles, the La index, and the impact beam plots) were recommended for bibliographical studies in the future.

Abbreviations: ARC = author articles, cited references and citing articles, DVT = deep vein thrombosis, IBP = impact beam plot, IRA = individual research achievement, MeSH = medical subject heading, RD = research domain, SNA = social network analysis, WOS = Web of Science.

Keywords: bibliometric analysis, impact beam plot, individual research achievement, La-index, research domain

1. Introduction
Defining research fields for individual authors is a significant challenge in information science.\[1\] Several early efforts focused on the sources of publications (e.g., journal names) to define research fields.\[2\] However, several multidisciplinary journals are included in the Web of Science (Thomson Reuters) and Scopus (Elsevier). As a result, many journals that are not organized along disciplinary lines have been added to databases (e.g., PLoS ONE and Medicine [Baltimore]), disrupting the existing classification of journals.\[3\] In response to these changes, bibliometricians have begun clustering the database\[4,5\] or applying Medical Subject Headings (MeSH) at the document level rather than journals alone.\[2\]

1.1. Using MeSH terms to cluster research domain for an individual author
Researchers have proposed the classification of research domains (RD) using MeSH terms\[2,4,7\] and social network...
1.2. Illustrations of the RD classification for authors

The abbreviated journal names in the references were used as an alternative to Web of Science subject categories to cluster MeSH terms, where referenced journals provide archival structures.[2] In contrast, MeSH terms reflect the most prevalent MeSH terms, where referenced journals provide archival structures in the future. Therefore, it is unclear whether RD can be consistently classified in ARCs. Therefore, we investigated the consistency of RD in ARCs.

1.3. A comparison of the research achievements of different authors

The 3 major components that may differ markedly in both the authors. An investigation of the La indices of the productive authors is needed.

1.4. Study aims

Our main objectives were, to compare the consistency of RD within ARC and to assess whether productive authors have an equal La index.

2. Methods

We downloaded 1388 abstracts from PubMed authored by 3 productive authors. One author, Chin-Hsiao Tseng (Taiwan), published 114 sole-author articles.[9,17] Another productive author was Chia-Hung Kao (Taiwan), who published 149 papers in 2015.[12,17] The third was Sung-Ho Jang (South Korea), who published 61 articles in Medicine (Baltimore).

As all data deposited in Supplemental Digital Content 1, http://links.lww.com/MD/H692 were obtained from a publicly available database, this study did not require ethical approval.

2.1. Approaches to achieving the study goals

The research has been divided into 2 parts, each achieving a different objective.

2.1.1 To compare the consistency of RD within ARC

For each author, a table of journal publications over time was generated. A Figure with network graphs in 3 panels was created using ARC (i.e., author articles, cited references, and citing articles) and SNA.

In this study, the joint paper network of a researcher was constructed using a bibliographic coupling, which is a similarity metric based on citation analysis in determining similarity in RD between 2 pieces of research. Consequently, this results in a network composed of multiple components and clusters representing different strands of research, which can be utilized to answer the question of whether the researcher’s research line is visible in the network.[18]

A. Networks in author articles

A 2-mode matrix of articles in the rows and MeSH terms in the columns was developed for the article list of the 3 authors.

B. Networks in cited references

Document age, number of coauthors, and citations in the La index are the 3 major components that may differ markedly between the authors. An investigation of the La indices of the productive authors is needed.
Bibliographic coupling\(^{[19–22]}\) is a measure of the similarity between papers in terms of shared cited references, and the number of shared cited references is normalized in relation to the total number of cited references in the 2 articles (e.g., using Salton’s cosine index\(^{[18]}\) in Equation 2, ranging from 0–1).

\[
\text{SaltonsCosineIndex} = \frac{F_{ij}}{\sqrt{S_i S_j}} \quad (2)
\]

where \(F_{ij}\) is the number of common references in papers \(i\) and \(j\), and \(S_i\) and \(S_j\) are the number of cited references in papers \(i\) and \(j\), respectively.

The dataset contains a 2-mode matrix of cited references in rows and MeSH terms in columns.

C. Networks in citing articles

The dataset contains a matrix of citing articles in rows and MeSH terms in columns, similar to cited references.

D. Betweenness centrality in SNA

Betweenness centrality was applied to SNA using Pajek software [in Koeln; PajekMan in Osoje (Ossiach, Austria)]\(^{[23]}\) through the following steps (see Supplemental Digital Content 2; http://links.lww.com/MD/H693):

| Table 1 | Publications of author Sung-Ho Jang (South Korea) as of May 24, 2022. |
|---------|---------------------------------------------------------------|
| Journal | 2003-> 11 12 13 14 15 16 17 18 19 20 21 2022 n ci IF |
| NeuroRehabilitation | 33 11 6 10 1 1 62 1074 17.32 |
| Medicine (Baltimore) | 0 2 13 15 10 4 7 7 3 61 233 3.82 |
| Neural Regen Res | 0 3 5 5 7 10 10 8 3 4 3 2 60 196 3.27 |
| Neurosci Lett | 12 4 9 5 4 3 1 1 1 40 1199 29.96 |
| Am J Phys Med Rehabil | 2 4 5 17 4 3 3 1 39 278 7.13 |
| Brain Inj | 0 1 1 2 3 3 4 1 15 160 10.67 |
| Eur Neurol | 5 4 5 1 15 257 17.13 |
| Int J Neurosci | 0 2 4 1 2 1 11 93 8.45 |
| Somatosens Mot Res | 0 3 2 3 2 1 11 91 8.27 |
| BMC Neurol | 0 1 3 1 1 3 1 10 51 5.10 |
| Others | 28 4 8 6 12 11 14 2 4 5 10 12 5 121 5691 12.79 |
| n | 80 26 31 36 33 36 62 39 26 16 26 23 11 445 5691 12.79 |

Note. IF = \(c_i/n = \text{citations/publications}\).

| Table 2 | Publications of author Chia-Hung Kao (Taiwan) as of May 24, 2022. |
|---------|---------------------------------------------------------------|
| Journal | 2002-> 11 12 13 14 15 16 17 18 19 20 21 2022 n ci IF |
| Medicine (Baltimore) | 0 74 34 2 2 4 1 117 1440 12.31 |
| Clin Nucl Med | 44 10 7 4 8 2 4 1 4 1 82 487 5.94 |
| PLoS One | 0 3 3 7 5 13 7 2 2 3 45 570 12.67 |
| Eur J Intern Med | 0 8 7 6 1 1 1 24 243 10.13 |
| Int J Environ Res Public Health | 0 9 9 6 24 131 5.46 |
| Anticancer Res | 14 2 16 464 29.00 |
| J Clin Med | 0 9 3 12 52 4.33 |
| BMJ Open | 0 1 3 2 1 4 11 25 2.27 |
| Front Pharmacol | 0 1 5 3 2 11 58 5.27 |
| Int J Cardiol | 0 3 1 6 1 1 11 164 14.91 |
| Others | 62 9 26 31 57 55 41 33 34 22 19 30 8 427 5640 13.21 |
| n | 120 19 38 41 81 149 99 46 63 47 29 37 11 780 9274 11.89 |

Note. IF = \(c_i/n = \text{citations/publications}\).

| Table 3 | Publications of author Chin-Hsiao Tseng (Taiwan) as of May 24, 2022. |
|---------|---------------------------------------------------------------|
| Journal | 2002-> 11 12 13 14 15 16 17 18 19 20 21 2022 n ci IF |
| Oncotarget | 0 4 1 4 5 9 347 38.56 |
| Circ J | 6 164 27.33 |
| Diabetes Care | 3 1 1 6 95 15.83 |
| PLoS One | 0 3 3 1 1 6 1 200 33.33 |
| Atherosclerosis | 3 1 1 5 118 23.6 |
| Eur J Clin Invest | 0 1 1 2 1 124 24.8 |
| J Environ Sci Health C | 2 1 1 1 526 105.2 |
| Environ Carcinog Ecotoxicol Rev | 5 413 82.6 |
| Toxicol Appl Pharmacol | 1 1 1 1 4 151 37.75 |
| Ann Med | 0 1 2 1 4 108 27 |
| BMC Cancer | 32 11 15 9 3 1 8 5 8 9 3 108 3883 35.95 |
| Others | 52 4 15 19 15 8 9 6 9 5 8 9 4 163 6129 37.6 |

Note. IF = \(c_i/n = \text{citations/publications}\).
Step 1: Document PMID (a.k.a. The PubMed reference number, which is a number assigned by the National Institutes of Health Library of Medicine to papers indexed in PubMed) in ARC, was extracted from icite analysis.[24]

Step 2: With the module in MS Excel in Supplemental Digital Content 3, http://links.lww.com/MD/H694, the control file used for Pajek[23] was generated.

Step 3: Create a partition using the algorithm of communities and a vector using the BC algorithm.

Step 4: Draw the SNA in the layout using a circular/use-partition algorithm in the layout panel of drawing SNA.

Step 5: We download the 3 digital files of, coordinates, clusters, and BC for the nodes.

Step 6: Produce the HyperText Markup Language, which creates the diagram shown on Google Maps. Larger bubble size indicates a higher BC in the network.

It is worth noting that BC is 1 of the most popular degrees of density in SNA. Few studies have applied the BC algorithm to interpret network characteristics. A quantitative scheme must be used to calculate the weights for each node as a bridge role, which is crucial to the network, and then to apply their relationships in comparison.[8] The top 3 representative MeSH terms with a higher BC in the clusters represent the RD for comparison in the ARC. We hypothesized that RD in productive authors would be consistent within ARC, as described in the first study goal.

2.1.2. To Assess authors having an equal La-index In addition to the La indexes, 2 other bibliometric indexes (e.g., h/-/x-indexes[14,15]) were also compared among the 3 illustrated authors.

Citations were extracted from the icite analysis.[24] Articles of each author were plotted on an impact beam plot[25] using the relative citation ratios (RCRs)[5] over the years.

The RCRs for each article were extracted from the icite analysis,[24] implying that the RCR values measure the scientific influence of each paper by field and time, adjusting the citations it has received and benchmarking to the median for National Institutes of Health publications.[5] Another hypothesis proposed that productive authors have an equal La index, as described in the second study goal.

2.2. Statistics and tools

All visualizations were performed in MS Excel. All materials used to draw the visual displays are referred to in Supplemental Digital Content 2, http://links.lww.com/MD/H693, and all dashboards were laid on Google Maps. The flowchart of the study is shown in Figure 1.

3. Results

3.1. To compare the consistency of RD within ARC

A total of 445, 780, and 163 articles were published by Sung-Ho Jang (South Korea), Chia-Hung Kao (Taiwan), and Chin-Hsiao Tseng (Taiwan), respectively; see Tables 1 to 3. Dr Jang’s RD is physiology/physiopathology, and Dr Kao and Dr Tseng’s RDs are epidemiology/diagnosis and epidemiology/complications; see Figures 2 to 4. As such, we confirmed the consistency of the RD terms by comparing the major MeSH terms in the ARC.

3.2. To assess authors having an equal La-index

Their La indexes were 5, 5, and 6 for Jang (South Korea), Dr Kao (Taiwan), and Dr Tseng (Taiwan), respectively, where a higher La index indicates more extraordinary research achievement.

In the IBPs (Figs. 5–7), we can see that their h-indexes were 37, 39, and 39 for Jang (South Korea), Dr Kao (Taiwan), and Dr Tseng (Taiwan), respectively. Meanwhile, their x-indexes were 75.87, 106.05, and 61.72 for Jang (South Korea), Dr Kao (Taiwan), and Dr Tseng (Taiwan), respectively, where a higher h(or x)-index indicates more extraordinary research achievements.

The most cited articles for the 3 authors are those[26–28] with citations = 304, 125, and 191, respectively; click on the right-most dots in IBPs to present articles in PubMed.

3.3. Online dashboards shown on google maps

The dashboards in Graphs appear once the QR code has been clicked. Readers are advised to examine the information details for each entity of interest.
4. Discussion

Two research goals have been achieved by observing the consistency of RD within the ARC and using the L-index calculation. One author with many single-authored articles receives more credit than 2 authors with few single-authored articles.

Based on the results, 445, 780, and 163 articles were published by Sung-Ho Jang (South Korea), Chia-Hung Kao (Taiwan), and Chin-Hsiao Tseng (Taiwan), respectively. Dr Jang’s RD is physiology, and Dr Kao and Dr Tseng’s RDs are epidemiology. We confirmed the consistency of the RD terms by comparing the major MeSH terms in the ARC. Their La indexes were 5, 5, and 6, where a higher value indicates more extraordinary research achievement.

4.1. Additional information

Unlike traditional bibliographical studies with descriptive statistics (e.g., publications, citations, and themes) in research, this study presents 2 distinct graphs, 1 grouping method using the L-index. It then confirms that the consistency of RD within ARC and the La indexes in authors are not equal. Using the RD defined by MeSH terms on articles is viable, and using the La index to classify the IRAs for authors is feasible.

Over 186 articles used CiteSpace and VOSviewer to conduct bibliometric analysis.[30] In bibliometrics, even though others use CiteSpace and VOSviewer for citation analysis, similar results were obtained using SNA, as in the current study; for instructions on drawing plots, see Supplemental Digital Content 2, http://links.lww.com/MD/H693.

The La index ranges from 5 to 6 for the 3 authors, and they are classified as PIs or exceptionally eminent scholars in the L-index.[16] Numerous proposals have been made to divide citations among coauthors.[31,32] In academic journals, the L-index has been applied to over 27 articles.[33] However, the only practical solution is to split them equally (i.e., to assign each coauthor 1/n of the authorities, where n is the total number of authors), as shown in equation 1. Although the author-weight
scheme was proposed to share article credits based on the order of the authors, it is straightforward to substitute $w_i$ for $1/a_i$ in equation 1. The author’s order is not considered in this study.

Furthermore, the primary reason for the inconsistency between $La$ and $h$-indexes is the citations adjusted by document age and coauthor number. Although their first publication started in almost the same years in 2002 and 2003, their mean coauthor numbers are distinctly different (i.e., 3.86, 5.96, and 2.24). Furthermore, Dr Tseng has the highest impact factor ($=37.6 = c/n$ in Table 3) compared to the other 2 ($= 12.78$ and $11.89$); see Tables 1–3.

4.2. Three most-cited articles on the IBPs

Dr Jang (South Korea) authored an article entitled “Repetitive transcranial magnetic stimulation-induced corticomotor excitability and associated motor skill acquisition in chronic stroke,” which was published in 2006. It was cited 304 times and classified as a physiopathology of the MeSH term. This study investigated high-frequency repetitive transcranial magnetic stimulation-induced cortical excitability and the associated motor skill acquisition in chronic stroke patients.

Dr Kao (Taiwan) authored an article entitled “Rheumatoid arthritis increases the risk of deep vein thrombosis (DVT) and pulmonary thromboembolism: a nationwide cohort study,”
| Year | n  | ci/article annually | median-29 h=37 | x=75.87 |
|------|----|---------------------|---------------|---------|
| 2003 | 3  | 58.67               |               |         |
| 2004 | 4  | 41.75               |               |         |
| 2005 | 6  | 53.50               |               |         |
| 2006 | 5  | 82.20               |               |         |
| 2007 | 13 | 32.46               |               |         |
| 2008 | 9  | 32.00               |               |         |
| 2009 | 17 | 32.18               |               |         |
| 2010 | 23 | 29.00               |               |         |
| 2011 | 26 | 14.42               |               |         |
| 2012 | 31 | 14.74               |               |         |
| 2013 | 36 | 13.69               |               |         |
| 2014 | 33 | 9.70                |               |         |
| 2015 | 36 | 9.25                |               |         |
| 2016 | 62 | 5.84                |               |         |
| 2017 | 39 | 4.03                |               |         |
| 2018 | 26 | 3.23                |               |         |
| 2019 | 17 | 3.41                |               |         |
| 2020 | 25 | 1.60                |               |         |
| 2021 | 23 | 0.52                |               |         |
| 2022 | 11 | 0.99                |               |         |

**Figure 5.** IBP of author Sung-Ho Jang (South Korea).

| Year | n  | ci/article annually | median=31 h=39 | x=106.05 |
|------|----|---------------------|----------------|----------|
| 2002 | 29 | 10.48               |               |          |
| 2003 | 36 | 11.33               |               |          |
| 2004 | 10 | 14.4                |               |          |
| 2005 | 5  | 39.2                |               |          |
| 2006 | 7  | 14.29               |               |          |
| 2007 | 5  | 14.2                |               |          |
| 2008 | 2  | 40.5                |               |          |
| 2009 | 9  | 3.67                |               |          |
| 2010 | 17 | 6.47                |               |          |
| 2011 | 19 | 12.58               |               |          |
| 2012 | 38 | 23.29               |               |          |
| 2013 | 41 | 16.51               |               |          |
| 2014 | 81 | 17.98               |               |          |
| 2015 | 149| 13.54               |               |          |
| 2016 | 99 | 13.63               |               |          |
| 2017 | 47 | 9.66                |               |          |
| 2018 | 61 | 6.3                 |               |          |
| 2019 | 48 | 4.96                |               |          |
| 2020 | 29 | 3.38                |               |          |
| 2021 | 36 | 0.83                |               |          |
| 2022 | 12 | 0                   |               |          |

**Figure 6.** IBP of author Chia-Hung Kao (Taiwan).
which was published in 2014. It has been cited 125 times and classified as epidemiological. This study aimed to examine the association between rheumatoid arthritis, DVT, and pulmonary thromboembolism. The multiplicatively increased risks of DVT and pulmonary thromboembolism were also significant in patients with rheumatoid arthritis and any comorbidities.

Dr Tseng (Taiwan) authored an article entitled “A review on environmental factors regulating arsenic methylation in humans,” which was published in 2009. It was cited 191 times and was classified as epidemiological. In this study, environmental factors affecting arsenic metabolism were reviewed. The study found that, methylation capacity might decrease with increasing dosage of arsenic exposure; women, especially during pregnancy, have better methylation capacity than their male counterparts; children might have better methylation capacity than adults; and age shows inconsistent relevance in adults.

4.3. Implications and changes

We provide 2 unique features in this study: the citation analysis using SNA with an MS Excel module deposited in Supplemental Digital Content 2, http://links.lww.com/MD/H693 and the IBP\textsuperscript{[25]} drawn online\textsuperscript{[36]} to visualize author research achievements, which complement the traditional visualizations\textsuperscript{[37–40]}(without specific reliance on intuitions of the visual display) on these 2 matters important to bibliometrics.

Unlike the La index, the h-index cannot exceed a scientist's total number of publications. However, several researchers of undisputed scientific merit, such as Sir Isaac Newton, Gregor Mendel, and Peter Higgs, have published a limited number of papers during their careers.\textsuperscript{[14]} As a result, they have h-indices of 4, 1, and 9, respectively, shockingly low. Other variants of the h-index that also consider publication counts suffer from the same shortcomings and should not be used to evaluate personal IRAs. Alternatively, they may be used to promote a grueling and futile pursuit of publication quantity at the expense of quality, as illustrated in the infamous “publish or perish” catchphrase.\textsuperscript{[40]} Fortunately, this issue has recently attracted the public’s attention with the San Francisco Declaration on Research Assessment, and some measures have been suggested.\textsuperscript{[41]}

Citations accumulate over time, so a researcher who started his career 30 years ago will likely have more citations than a young researcher, but this does not necessarily imply that the former is a better scientist. Highly cited papers are likely to receive more citations.\textsuperscript{[42]} Consequently, citations exhibit the characteristic of preferential attachment, resulting in their distribution following a power law.\textsuperscript{[43]} In this regard, it is necessary to adjust for the age of publication to assess the current capabilities and impact of researchers rather than their past achievements and partially compensate for a preference for older publications. It would appear that the number of citations divided by the age of the publication in years is an appropriate measure since it reflects the power-law distribution of citations. Therefore, we used the La index to classify the author IRAs.

Furthermore, a scientist who has made such an important discovery will remain at the forefront, regardless of how many years have passed since its publication. Examples of this can be found in IBPs. Although the original articles were published many years ago, their La indices are still higher.

4.4. Limitations and suggestions

Future research must thoroughly examine several issues. First, only the La index was used to calculate personal IRAs. Further research is encouraged to determine whether other bibliometric indices can also be used to stratify the IRAs.
Second, while the La index is recommended for stratifying IRAs with natural breaks (i.e., the logarithmic scale), as is the L-index,[1] the premise that the coauthors are all given equal credit for an article can differ if this assumption is not upheld.

Third, Google Maps displayed the dashboards in Figures 2 to 7. These installments are not accessible because the Google Maps application programming interface requires a product key. The dashboard has the limitations that it is not publicly accessible without permission from Google. It is difficult for other authors to replicate it for use in a short period.

Fourth, only 3 authors were included in this study due to space constraints. In Supplemental Digital Content 2, http://links.lww.com/MD/H693, we provide detailed instructions regarding creating visualizations that can be applied to other productive authors in the future.

Finally, IBP is unique and modern and can be applied to other authors, but details of IBP production are not discussed in this study. The procedure for creating an IBP is easy and can be done online.[34] Readers were invited to submit their articles and click on the submission icon to display the IBP on Google Maps.

6. Conclusion

Using visualizations and the La index, we found that, RD is consistent within ARC, and the La indexes in productive authors are not equal. In future relevant bibliographical studies, 2 different graphs (citation analysis using SNA and IBP) and the La-index grouping method are recommended for researchers, not just for authors, as illustrated here.

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Author contributions

SYC and KT provided the concept and designed this study, SYC and TWC interpreted the data, CC and KT monitored the process and the manuscript. TWC and SYC drafted the manuscript. All authors read the manuscript and approved the final manuscript.

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