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Peer review and the *h*-index: Two studies

Michael Norris, Charles Oppenheim*

Department of Information Science, Loughborough University, Ashby Road, Loughborough, Leics LE11 3TU, UK

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ABSTRACT

Research was undertaken that examined what, if any, correlation there was between the *h*-index and rankings by peer assessment, and what correlation there was between the 2008 UK RAE rankings and the collective *h*-index of submitting departments. About 100 international scholars in Library and Information Science were ranked by their peers on the quality of their work. These rankings were correlated with the *h* and *g* scores the scholars had achieved. The results showed that there was a correlation between their median rankings and the indexes. The 2008 RAE grade point averages (GPA) achieved by departments from three UoAs – Anthropology, Library and Information Management and Pharmacy were compared with each of their collective *h* and *g* index scores. Results were mixed, with a strong correlation between pharmacy departments and index scores, followed by library and information management to anthropology where negative and non-significant results were found. Taken together, the findings from the research indicate that individual ranking by peer assessment and their *h*-index or variants was generally good. Results for the RAE 2008 gave correlations between GPA and successive versions of the *h*-index which varied in strength, except for anthropology where, it is suggested detailed cited reference searches must be undertaken to maximise citation counts.

1. Introduction

In 2005, Hirsch proposed a simple and intuitively attractive measure of an individual's impact in their field – the *h*-index (Hirsch, 2005, p. 16569). Hirsch defined the index as follows:

> A scientist has index *h* if *h* of his/her N_p papers have at least *h* citations each and the other papers have no more than *h* citations each. . .

Hence a scholar who has an *h*-index of 5 has at least five papers with at least five citations each, but does not have six papers with at least six citations each. The index has generally been well received (Ball, 2005) and has been adopted by the major citation database suppliers and authors can, for example, using Scopus or the Web of Science quickly calculate their own *h*-index. Since Hirsch's original paper in 2005, many articles have been published which have discussed the *h*-index in relation to its perceived advantages and disadvantages, its mathematical derivation, and variants to the index which address some of its shortcomings (e.g. Bornmann & Daniel, 2007; Bornmann, Mutz, & Daniel, 2008; Costas & Bordons, 2007; Egghe, 2006; Glänzel, 2006a, 2006b; Hirsch, 2005; Jin, Liang, Rousseau, & Egghe, 2007; Liu & Rousseau, 2009).

Unlike other measures, the *h*-index gives a broadly balanced and cumulative view of an individual's impact, rather than just counting citations an author has or the number of publications they have accumulated (Bornmann & Daniel, 2007).

* Corresponding author. Tel.: +44 1509 223065; fax: +44 1509 223053.
E-mail address: C.Oppenheim@lboro.ac.uk (C. Oppenheim).

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The index tends to favour those scholars who have produced a stream of publications which have steadily accrued good citation counts. Robustness is an important issue and Braun, Glänzel, and Schubert (2006, p. 170) find that the *h*-index is "...insensitive to an accidental excess of uncited papers and also to one or several outstandingly highly cited papers. Second, it combines the effect of "quantity" (number of publications) and "quality" (citation rate) in a rather specific, balanced way that should reduce the apparent overrating of some small review journals."

Whilst much of the work on the *h*-index has investigated its properties, there has been little work that has sought to see how well the results of peer review can be correlated with the *h*-index. Notable exceptions to this have included Van Raan (2006), who looked at 147 chemistry university research groups working in the Netherlands. Bornmann and Daniel (2005) examined post-doctoral research fellowships and Bornmann, Wallon, and Ledin (2008) considered the applicants for long-term fellowships and young investigator programmes to the European Molecular Biology Organization.

The research also uses the *g*-index first introduced by Egghe (2006) as an additional comparative measure with the *h*-index. The *g*-index, like the *h*-index is used to see what correlation there was between the index and rankings by peer assessment. The *g*-index takes more account of those highly cited articles, which once included in the *h*-index, are not 'used' in future calculations. Egghe (2006) explains and defines the *g*-index as:

> ... an improvement of the *h*-index of Hirsch to measure the global citation performance of a set of articles. If [a set of articles] is ranked in decreasing order of the number of citations that they received, the *g*-index is the (unique) largest number such that the top *g* articles received (together) at least g^2 citations.

Thus an author with a *g*-index of 12, whose articles are ranked in order of their citation count, will have accumulated at least 144 citations but will not have 13 articles which have accumulated 169 citations between them.

The research here takes two approaches, where the results of a peer review process, one at individual level and a second at a collective level are compared to their respective *h*-index scores. At the individual level, an expert panel of academics in library and information science were asked, using an online questionnaire, to rank a hundred or so of their peers. At the collective level of the research, the results from the peer review process from three Units of Assessments (UoAs) from the 2008 UK Research Assessment Exercise (RAE) were taken for analysis.

2. Methods

2.1. Individual level

Research was conducted on 101 library and information science academics drawn from 16 different countries. Some were drawn from the earlier research of Cronin and Meho (2006), Oppenheim (2007) and Sanderson (2008), who calculated the *h*-index scores of a number of US and UK scholars active in the discipline. However, to ensure a relatively broad selection of academics at various stages of their career and from a range of countries, the publication records of other authors publishing in the field over the last 10 years (1998–2008) were compiled. Using Thomson Reuters Journal Citation Reports (JCR), a number of journal titles were selected from the Information Science and Library Science subject category. Journal and review articles from these titles were ranked by author productivity. From these, a completely random sample of authors who had written 15 or more articles over the 10-year period was taken. There was no attempt to select scholars on the basis of known standing in the discipline, so many well known scholars were not selected, for example Tibor Braun, Jack Meadows or Eugene Garfield.

A web based questionnaire was designed to assess the perceived ranking of the 101 academics. A ranking scale was devised which allowed participants to rank an academic's impact from them not meriting national recognition to work that was world leading in terms of originality, significance and rigour. After piloting the questionnaire, an expert panel of 58 academics were invited to evaluate the 101 academics. The panel comprised of 44 academics randomly drawn from the 101 scholars being evaluated and 14 journal editors whose journals were part of the JCR Information Science and Library Science subject category. Editors and their journals were selected on the basis of having a wide and representative view of the discipline. The 58 academics were invited by email to participate in the ranking exercise. Of those invited, a number declined or did not reply. Of the 45 who did agree to participate, 42 completed the questionnaire, an overall success rate of 72%. These 42 were asked only for their country of work and were asked not to rank themselves if they appeared on the list. The expert panel were asked to select from the 101 academics who they wished to rank and then were able to rank them according to the scale shown in Appendix A. From these results, a median ranking was calculated for each academic.

As an aid to identifying published items, lists of the 101 academic's publications were sought and usually found at their homepage, or could be assembled from other listings, for example from departmental publication lists or institutional repositories. If this was insufficient, then the author was contacted directly for a list of their publications. With the aid of the publication lists, citations to the 101 individuals were counted using Thomson Reuters' Web of Science; all three of the citation indexes were used. Combinations of the author's initials were used if necessary to identify relevant citations as well as known name variations. A General Search was conducted to gather the core of the author's work and their citations; this was supplemented by a Cited Reference Search that enabled mis-citations and items not indexed by WoS to be included along with their citation counts. A 12-year period of 1996–2008 was used to count citations; items included were journal articles, review articles, books, book chapters, conference proceedings and reports. Letters, corrections, editorials, book reviews, meeting abstracts, and their citations were excluded. Citation counts to items that were co-authored by any of the

101 academics were given in full to each author irrespective of the number of co-authors. Where authors had published in disciplines other than information science, these publications were discounted.

Three sets of citation data were calculated for each academic who appeared in the questionnaire:

(A) Taken from the WoS's General Search where only citations to items indexed by WoS are recorded.
(B) Using the core citations found from (A) but augmented by additional items and their citations found through the WoS's Cited Reference Search.
(C) The same as (B) but with the individual academics' self-citations removed.

The data was downloaded to a prepared spreadsheet application, which allowed the calculation of the *h* and *g* indexes. Author self-citations were identified and several models of the citation data with respective *h* and *g* indexes were created.

2.2. Collective level

Earlier work has shown statistically significant correlations between Research Assessment Exercise (RAE) results and the collective citation counts of submitting authors or departments across a number of different Units of Assessment (UoA) (Norris & Oppenheim, 2003; Oppenheim, 1997). For the 2008 RAE, UK university departments made submissions as for earlier assessments. Unlike these earlier RAE assessments however, where departments were given an overall rating for research quality, the results from this latest exercise were based on quality profiles where submissions were graded into one of the five categories:

4* – Quality that is world leading in terms of originality, significance and rigour.
3* – Quality that is internationally excellent in terms of originality, significance and rigour but which nonetheless falls short of the highest standards of excellence.
2* – Quality that is recognised internationally in terms of originality, significance and rigour.
1* – Quality that is recognised nationally in terms of originality, significance and rigour.
0* – Quality that falls below the standard of nationally recognised work. Or work which does not meet the published definition of research for the purposes of this assessment (RAE 2008, n.d.).

In the peer review process, the percentage of the research activity judged to meet the above standards was made and these form the basis of the quality profiles reported by the RAE. To allow overall rankings of universities and departments to be made, by HEFCE, a 'grade point average' (GPA) calculation was devised. This is found by successively multiplying the number of staff submitted by the percentage of their work found in the different grades and then dividing the sum by 100.

Rather than assessing just the correlation between citation counts and GPA scores, *h* and *g* index scores and some of their variants were derived for those departments who made submissions to UoA 37 – Library and Information Science, UoA 42 – Anthropology and UoA 13 – Pharmacy and then correlated to their respective GPA scores. The three subjects were chosen with past research in mind with which they could be compared, either directly, or with close parallels drawn to other subjects that have been the subject of similar research. The chosen subjects ranging, on a small scale, between the sciences and the humanities. Similarly the WoS General Search was used to count citations rather than using cited reference searches, in an attempt it is suggested, to mimic the processes that may be adopted by the future Research Excellence Framework (REF) and hence provide some evidence of the predictive power of the method. This approach is predicated on the notion that the future REF (HEFCE, n.d.) is likely to include some bibliometric indicators and that these will be derived, it is assumed, only from the items indexed by the database provider, rather than trying to count additional citations to items not indexed by them through, for example, a cited reference search which can be very labour intensive.

A subset of the RAE 2008 data was obtained as an Access file from HEFCE which detailed the academics who were submitted to the three UoAs given above and their submitted publications. The lists were examined and only category 'A' FTE staff were included in the research. This resulted in the exclusion of some 28 category 'C' academics.[1] The number of citations the category 'A' authors had to all of their published items between 2001 and 2007, not just their submitted items, were counted using the WoS General Search. The items included were journal articles, review articles, books, book chapters, conference proceedings and reports. Letters, corrections, editorials, book reviews, meeting abstracts, and their citations were excluded. The total number of citations for each department was recorded and a departmental mean author citation count was calculated. Individual author *h* and *g* index scores were also noted. The collective cited items and their citation counts on a departmental basis were ranked and

[1] Category 'A' staff are academics who were employed by their submitting department on the census date and were involved in research and/or teaching, whereas 'C' category staff are independent investigators active in research who do not meet the definition of category 'A' staff, but whose research on the census date is focussed in the department that returns them.

Table 1
Academics by workplace.

Country	Frequency	Percent
Australia	2	2.0
Belgium	4	4.0
Canada	6	5.9
Denmark	2	2.0
Finland	3	3.0
France	1	1.0
Germany	1	1.0
Hong Kong	1	1.0
Hungry	1	1.0
India	2	2.0
Israel	1	1.0
Netherlands	4	4.0
Singapore	1	1.0
Spain	1	1.0
UK	40	39.6
USA	31	30.7
Total	101	100.0

Table 2
Frequency of *h*-index scores.

h-Index	Frequency
2	5
3	10
4	16
5	9
6	14
7	10
8	5
9	11
10	4
11	6
12	2
13	3
14	2
17	2
18	1
30	1
Total	101

departmental[2] *h* and *g* indexes were calculated. Also for all of the departments a successive author[3] *h* and *g* index was calculated.

The GPA was taken from published results for all of the UoAs for the university departments (RAE 2008, n.d.) and these were ranked against total citation counts, mean author citations and the two sets of variants of the *h*/*g*-index scores, Spearman Rank Order Correlation Coefficients were then calculated. Spearman's Rank Order Correlation was used as it allows the correlation between variables to be calculated, when the data for such variables does not follow the normal distribution (Diamantopoulos & Schlegelmilch, 1997). Citation counts were taken from the WoS (1945–2009 edition) citation database through Mimas during August 2008 and March 2009. Correlations between the datasets and some of the metrics were calculated using SPSS (version 16.0) statistical software.

3. Results

3.1. Individual level

Academics appearing in the questionnaire were drawn from 16 countries and these are shown in Table 1, with 70.3% of these originating from the UK and the USA. There was a gender split in favour of males who accounted for 76.2% of the total, females were mostly evident in the USA and the UK.

All of the academics examined achieved *h* and *g* scores of 2 or above with a range of 2–30 for the *h*-index and 2–59 for the *g*-index. Table 2 shows a breakdown of the frequency of *h*-index scores for the citation data (A).

[2] All cited items from a submitting department are ranked irrespective of author and *h* and *g* index scores derived.
[3] A department with a successive author *h*-index of four will have four authors with at least an individual *h*-index of four. Similarly a department with a successive *g*-index of four will have four authors with at least an individual *g*-index of four.

Table 3
Comparative movements between citation datasets.

	h-Index citation datasets			*g*-Index citation datasets		
	A/B	A/C	B/C	A/B	A/B	B/C
Min rank	−18	−36	−23	−17	−37	−32
Max rank	55	55	12	58	58	18
Range	73	91	35	75	95	50

Spearman's Rank Order Correlation was used to assess the individual correlation of the *h* and *g* scores, with the overall median scores calculated from the rankings of the expert panel. Results were significant, at the 0.01 level, with scores ranging, for the different citation datasets, between 0.397 and 0.518 for the *h*-index and 0.484 and 0.534 for the *g*-index. Given that almost 40% of the subjects in the questionnaire were from the UK, Spearman's Rank Order Correlation was used to assess the correlation of the *h* and *g* scores for just those UK academics and the rankings from only UK expert panel members. The significant results are shown in Appendix B and show little variation from when all the academics were included. These results show that where citation counts were made using cited references searches, less any self-citations, that these gave the highest correlations between the median rankings and the *h*/*g* index scores. Similar calculations were undertaken for just USA academics as well as separate tests by gender and rankings; these proved almost exclusively to give non-significant results.

Appendix C shows the individual index scores and ranking for each of the academics included in the questionnaire by the three sets of citation data for the *h* and *g* indexes. The rankings vary, with a number of them tied. The *h*-index has between 16 and 19 tied ranks and the *g*-index has between 24 and 27 depending on the citation dataset used. Comparisons of the citation datasets A to B, A to C and B to C by ranked index position give respectively overall mean differences in terms of position changes of, a negative movement of 0.5 places, a positive movement of 0.32 places and a positive movement of 1 place. For the same comparison but for the *g*-index data the results were respectively a negative movement of 0.4 places, a negative movement of 0.1 places and no movement at all. Overall, the mean movement in the rankings are not unduly affected by the citation dataset used to calculate rankings. However, this masks some large movements in the results when the rankings are compared on an individual basis for each academic between citation datasets. The ranges of these variations are given in Table 3 which shows the minimum and maximum movements in ranking caused by changes in citation counts by the inclusion and exclusion of, for example self-citations between citation datasets.

Feather, for example, has a *h*-index of 2 when using the General Search (A) citation data, but this changes to 5 when citation data using the Cited Reference Search (B) data is used. In this case, citations to books not indexed by the WoS being counted affect his position, with his ranking rising from 97th to 77th position. This changes again when the level of self-citation is taken into account; Feather's ranked position then rises a further 12 places to 65th position. Another notable example on the same basis as Feather is Harnad, whose original *h*-index was 3, with this rising to 9 with a commensurate change of rank from 87 to 32 with no further movement thereafter when self-citations are excluded from the calculation. Thelwall, who has a self-citation rate of 53.2%, finds his original *h*-index falling from 17 to 11 when his self-citations are discounted and his ranking falls from joint third to joint 13th position. Generally, where an author has a large number of self-citations and these are discounted, then their position in the rankings will fall. However, given the density of the tied rankings in the interquartile range, those who were originally in this range of rankings before or after adjustments will see larger swings in their relative ranked position than those who are nearer the extremities of the rankings and have fewer self-citations.

Cole has a self-citation rate of 50%, followed by Huntingdon and Jamali who each have self-citation rates of about 41%. The latter two frequently published together as joint authors and hence have almost exactly the same self-citation profile. Whilst Thelwall's ranking is affected by his self-citation rate, Cole, Huntingdon and Jamali were similarly affected. Taking the movement between citation datasets A to C, Cole's ranking drops from 22 to 55, Huntingdon's from 18 to 41 and Jamali's 62 to 92. A similar result is also evident when the movement of *g* scores is examined, with Thelwall falling 19 places in the ranking, Cole falling 30 places, Huntingdon falling 37 places and Jamali 17 places. Overall, the percentage of self-citations was 16.0%, ranging for females between Kuhlthau's 2.4% to Ounis at 27.8, and for males between Thelwall's 53.2% to Feather at 1.2%.

3.2. Collective level

In all, 1065 FTE staff were submitted to the three departments. When non-category 'A' staff were removed this gave net staff numbers of 286 for Library and Information Management, 429 for Pharmacy and 322 for Anthropology, with the majority of authors submitting four publications each. Individual and collective citation counts for the departments varied between subjects with some authors recording zero counts to some very high scores, most notably in pharmacy. Taking overall citation counts by UoA and total staff counts, the mean citation scores per academic were Pharmacy 284, Anthropology 28 and Library and Information Management at 31. Clearly, citation counts and author productivity was generally much higher for the pharmacy academics than for the other two subjects.

The number of FTE academics submitted for assessment, by department, varied considerably; the range for library and information management was between 3 and 50 staff, for anthropology this was 7 and 37 and for pharmacy this was 12 and 60. The number of staff submitted did not necessarily correlate with a corresponding GPA ranking, Wolverhampton, with just 4 submitted, staff came joint second in library and information management, whereas Strathclyde, who submitted 60 staff, had a joint sixth mid-position in pharmacy, and for anthropology, Roehampton who submitted 7 staff was ranked fourth.

For library and information management, significant correlations were found between the GPA ranking and *h* and *g* indexes and the successive author *h*-index and total citation count by department, but non-significant correlations were found for the other measures. For pharmacy, significant results were found for all the measures. Anthropology, on the other hand, showed non-significant negative correlations for all measures. The majority of these correlations only became significant, whilst still remaining negative, when the departmental submission from Cambridge University (Cambridge B: Biological anthropology) was removed from the calculation, see Appendix D for this and other results. These results show that the successive *h* and *g* indexes were shown to have the better correlations rather than their single status counterparts. Except for pharmacy and only marginally so, the next highest correlations were for the total citation count or the mean author citation count for the submitting department.

4. Discussion

4.1. Individual level

The *h* and *g* indexes scores varied dependent on which set of citation data had been used. As Cronin and Meho (2006) and Oppenheim (2007) noted, when using WoS, the Cited Reference Search gives a more reliable profile of an academic's citation count, including as it does mis-citations and citations to non-indexed items such as monographs. Whilst individual *h* and *g* scores varied between the different citation datasets this was quite limited. When academics were ranked by their overall scores, movements between them were almost cancelled out. However, far more variability was evident when academics were ranked overall by their respective *h* and *g* scores and their movements in the rankings noted. Changes in overall rankings were evident for those academics whose publication records contained citations to non-indexed items on WoSs General Search and were later counted through a Cited Reference Search or those who were heavy self-citers. Differences were, however variable, dependent for example on the levels of self-citation and the position in the rankings. Given the density of tied ranks in the mid-range of scores, drops in *h*-scores caused by the removal of self-citations can cause what appears to be disproportionate falls in an individual's overall ranking. There appears to be a little less sensitivity to movements in the rankings caused by changes in citation counts for those academics who are positioned at either ends of the rankings.

Comparison of the *h*-index scores and rankings obtained in this research with the American academics found in Cronin and Meho (2006) show a remarkable consistency considering the different time period, which was the academic's lifetime compared to the 12-year period taken here for the citation counts. Both studies had 28 US academics in common and their *h*-indexes were calculated both with and without self-citations. The Spearman Rank Order Correlation between the two sets of results was 0.802 with self-citations and without self-citations was 0.805 with both results being significant at the 0.01 level. These results suggesting that the *h*-index remains a fairly consistent measure of impact even when dissimilar timeframes are used. A similar comparison was made with data from a study by Adkins and Budd (2006) who ranked 25 US academics by their gross citation count between 1999 and 2004, with in this case 15 academics in common between the two studies. However, the gross citation ranking of the 15 academics and their *h*-indexes including all their citations gave a non-significant Spearman Rank Order Correlation result, suggesting in this case at least, that gross citation counts may give a less consistent result between different time frames than the *h*-index.

Results from the Spearman Rank Order Correlation between all the median rankings by the expert panel and the *h*-index and variants in this study were significant, ranging from 0.397 and 0.518. Kraemer et al. (2003) consider these results to be medium or typical to large or larger than typical effects for the relation between these variables. The results for the UK only, taken overall were about the same. In both cases, however, correlations were stronger for citation datasets which were based on WoS Cited Reference Searches (CRS), which allow for the counting of citations to non-indexed items as well as those items indexed by WoS and ordinarily accessed through a WoS General Search. The highest correlations were found for CRS citation datasets which used the *g*-index and excluded self-citations giving large or larger than typical effects (Kraemer et al., 2003). It is clear that there is a greater range of ranks for the *g*-index, allowing those scholars with many highly cited items to have them included whereas the *h*-index is less sensitive to highly cited items. Despite the limited number of median rankings (8) from the peer review process, it may be reasoned that the greater range of *g* scores helped to produce a better correlation between peer rankings and the *g*-index. Whilst as discussed above, overall rankings are little affected by the rate of self-citation and hence collective assessments are likely to be only marginally affected, it is clear that there is a better correlation when these are excluded and if ranking on an individual basis their exclusion seems to be a wise strategy, especially where the discipline has a tendency to self-cite, as in physics (Schreiber, 2007).

The correlation found by Cronin and Meho (2006) for LIS scholars between their citation counts and their *h*-index ranking was high (0.9) and significant, but this is not a surprising result since both rankings where drawn from the same citation pool. A not dissimilar level of correlation was found by Bornmann, Wallon, et al. (2008, p. 153) in their work with molecular

scientists, between that is, the number of citations and the number of publications the scientists had with their *h*-index. They also usefully note similar results for the convergence of the *h*-index with citation counts for other studies across a number of disciplines, thus confirming the undoubted correlation that there is between these two measures. More importantly, Bornmann and Daniel (2005) note the success of the *h*-index in identifying those awarded research fellowships and peer review rankings of them by the awarding committee. Similarly, confirming this result, Bornmann, Wallon, et al. (2008) on a broader scale but with a different dataset noted that those researchers who were successful at getting research funding had statistically higher *h*-indexes than those who where less successful at getting funding.

4.2. Collective level

The earlier work of Oppenheim (1997) and Norris and Oppenheim (2003) showed strong correlations between overall and average citation counts and the rating given by the RAE for the 1992 and 2001 rankings. In the case of Oppenheim's (1997), research he used academics found in the relevant departments listed in the *Commonwealth Universities Handbook* for the subjects he was interested in. Norris and Oppenheim (2003) were able to identify the actual staff submitted for assessment and hence count only citations to their work. For the three UoAs examined here, it was also possible to count citations to only those staff who had been submitted. In the case of library and information management correlations appeared as having a medium or typical effect between the GPA rankings and the *h* and *g* indexes as well as the successive author *h*-index, correlations between mean author citation counts were non-significant. This result is contrary to the earlier work mentioned above, where a very strong correlation was found between RAE rankings and citation counts and in particular in Oppenheim's 1995 paper which examined the correlation between UK library and information science departments and the 1992 RAE rankings; here he found Spearman Rank Order Correlation results between citation counts and the rankings around 0.80 and significant at the 0.01 level. However, GPA rankings allow for a much finer grading than the former more coarsely rated RAE scale. For the library and information management UoA 14 GPA rankings resulted from the calculations as against the seven possible ratings from the 2001 RAE.

The Spearman Rank Order Correlation results for pharmacy were, however, all significant at the 0.01 level and much stronger ranging from 0.70 for the *g*-index to 0.91 for the successive *h*-index. A result which Kraemer et al. (2003) regard as demonstrating a much larger than typical effect between the variables. Pharmacy as a science subject predictably relies more heavily on journals to disseminate findings and has a strong citation culture, as is evident in the high number of citations found. The work is paralleled by the work of Oppenheim (1997), where he found a strong correlation between the RAE rankings and citation counts for genetics, using in this case a WoS Cited Reference Search to count citations. The two subjects have almost identical coverage by the WoS (Moed, 2005, p. 129).

The results for anthropology were contrary to those expected, with all the Spearman Rank Order Correlation results being negative and non-significant. The subject is less well covered in the WoS citation indexes (Moed, 2005, p. 130) and is reliant on monographs or contributions to them for the dissemination of research findings. The subject, is however, very similar to archaeology which is in fact less well covered in the WoS than anthropology (Moed, 2005, p. 130). When Oppenheim (1997) and Norris and Oppenheim (2003) compared RAE rankings for archaeology departments and citation counts to their submitting academics, they found a strong positive correlations, using citations found using WoS Cited Reference Searches.

Correlations between the GPA rankings and the different *h*/*g*-indexes showed some variation. What was noticeable though was for library and information management and pharmacy that the successive *h*-index had a higher level of correlation than any of the other variants. In anthropology, the successive *h* and *g* indexes were almost the same but better than the individual *h* and *g* scores. The successive *h* and *g* indexes tend to measure the depth of performance of a department by identifying how many scholars have comparative *h* or *g* index scores rather than any of the single indexes which can easily be inflated by the work of one or two high performing academics. This result tends to suggest that depth of overall performance more realistically reflects the RAE peer ranking process.

Noticeable differences in the range of topics covered were observed between the disciplines during the collection of citations; this was particularly apparent for pharmacy when compared to the other two subjects. For pharmacy, the subject was split between dispensing practice and research. Submissions to library and information management varied widely and included mathematical and computer science oriented submissions as well as diverse library and information management topics. Submissions made by Kings College London exemplify this diversity where the few indexed items found for the College were centred on their Centre for Computing in the Humanities department, generating a very varied range of items submitted. The department came second in the rankings for the UoA but no citations to their work were found. For an anthropological example, Cambridge University made two separate departmental submissions, one recognisably similar to the contribution of others which they called 'social anthropology', whilst their separate 'biological anthropology' submissions were noticeably more scientific in their approach and had a far higher mean author citation count. It was only when this latter submission was removed from the calculations that correlations were found, albeit negative.

5. Conclusions

There is a correlation between the peer ranking of individual library and information science scholars and their *h*-index. There is also a correlation between some subjects and their recent GPA score taken from the 2008 RAE. Several approaches were taken to identify which citation counting strategies were the most appropriate to yield a range of correlation statistics.

These approaches demonstrated that in the case of ranking individual library and information science scholars that a cited reference search, less self-citations, yielded the best correlation statistic.

In the research which featured the recent 2008 RAE results it was shown that for library and information management and pharmacy in particular, there was a correlation between GPA rankings and *h*/*g* indexes and some of their variants. There was a less successful result for anthropology. The successive variants of the *h*/*g* indexes were shown to yield the strongest correlations for the former two subjects. In an attempt to foreshadow a citation counting technique that might be used for the future Research Excellence Framework, citations were deliberately limited to those found using the WoS General Search which limits counts to items it indexes. This seems to be very effective for the science based subjects like pharmacy, with its culture of journal publication. For library and information management, the strategy was also effective, but for anthropology with its weak negative correlation, this proved to be less so. For any subject which is less well covered by WoS, a cited reference search or its equivalent would yield a more realistic citation count from which to derive *h*-index scores.

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Appendix A. Ranking categories for the questionnaire

The categories are based on the quality assessment definitions used by the UKs 2008 Research Assessment Exercise:

4* – His or her work that is world leading in terms of originality, significance and rigour.
3* – His or her work that is internationally excellent in terms of originality, significance and rigour but which nonetheless falls short of the highest standards of excellence.
2* – His or her work that is recognised internationally in terms of originality, significance and rigour.
1* – His or her work that is recognised nationally in terms of originality, significance and rigour.
0* – His or her work that does not merit national recognition.

Appendix B.

Spearman Rank Order Correlation of *h* and *g* indexes with all median values from questionnaire ranking for all academics

		H(A)	*G*(A)	*H*(B)	*G*(B)	*H*(C)	*G*(C)
Spearman's rho	Correlation Coefficient	.397**	.484**	.484**	.531.**	.518**	.534**
	Sig. (1-tailed)	.000	.000	.000	.000	.000	.000
	N	101	101	101	101	101	101

** Correlation is significant at the 0.01 level (1-tailed).

Spearman Rank Order Correlation of *h* and *g* indexes with UK median values from questionnaire ranking for UK academics only.

		H(A)	*G*(A)	*H*(B)	*G*(B)	*H*(C)	*G*(C)
Spearman's rho	Correlation Coefficient	.462**	.487**	.464**	.508.**	.536**	.516**
	Sig. (1-tailed)	.001	.001	.001	.000	.000	.000
	N	40	40	40	40	40	40

Key. *H*(A)/*G*(A): Citation counts by General Search – with self-citations included. *H*(B)/*G*(B): Citation counts by General Search augmented by Cited Reference Search. *H*(C)/*G*(C): Citation counts by General Search augmented by Cited Reference Search with *h*/*g* – author self-citations removed.

** Correlation is significant at the 0.01 level (1-tailed).

Appendix C. *h* and *g* index author ranking by citation datasets

Author	Rank	*H*(A)	Author	Rank	*H*(B)	Author	Rank	*H*(C)	Author	Rank	*G*(A)	Author	Rank	*G*(B)	Author	Rank	*G*(C)
Willett, P	1	30	Willett, P	1	27	Willett, P	1	27	Willett, P	1	59	Willett, P	1	55	Willett, P	1	55
Spink, A	2	18	Thelwall, M	2	21	Spink, A	2	18	Spink, A	2	33	Spink, A	2	35	Spink, A	2	31
Glanzel, W	3	17	Spink, A	3	20	Glanzel, W	3	15	Ingwersen, P	3	26	Thelwall, M	3	29	Ingwersen, P	3	27
Thelwall, M	3	17	Glanzel, W	4	17	van Raan, AFJ	4	14	Thelwall, M	3	26	Ingwersen, P	4	28	Jansen, BJ	4	24
Rousseau, R	4	14	Leydesdorff, L	5	16	Wilson, TD	4	14	Glanzel, W	4	23	Jansen, BJ	5	26	Wilson, TD	5	23
van Raan, AFJ	4	14	Rousseau, R	6	15	Moed, HF	5	13	Jansen, BJ	4	23	Leydesdorff, L	6	24	Glanzel, W	6	21
Ford, N	5	13	van Raan, AFJ	6	15	Rousseau, R	5	13	Leydesdorff, L	4	23	Wilson, TD	6	24	Leydesdorff, L	6	21
Leydesdorff, L	5	13	Ford, N	7	14	Ford, N	6	12	van Raan, AFJ	5	22	Glanzel, W	7	23	Moed, HF	6	21
Moed, HF	5	13	Moed, HF	7	14	Leydesdorff, L	6	12	Moed, HF	6	20	Rousseau, R	7	23	Rousseau, R	6	21
Cronin, B	6	12	Tenopir, C	7	14	Saracevic, T	6	12	Cronin, B	7	19	van Raan, AFJ	7	23	Tenopir, C	6	21
van Leeuwen, TN	6	12	Wilson, TD	7	14	Tenopir, C	6	12	Rousseau, R	7	19	Moed, HF	8	22	van Raan, AFJ	6	21
Bar-Ilan, J	7	11	Egghe, L	8	13	van Leeuwen, TN	6	12	White, HD	7	19	Tenopir, C	8	22	Borgman, C	7	20
Hjorland, B	7	11	Hjorland, B	8	13	Cronin, B	7	11	Wilson, TD	7	19	Borgman, C	9	21	Saracevic, T	7	20
Meyer, M	7	11	Cronin, B	9	12	Ingwersen, P	7	11	Ford, N	8	18	Hjorland, B	9	21	Cronin, B	8	19
Nicholas, D	7	11	Ingwersen, P	9	12	Jansen, BJ	7	11	Borgman, C	9	17	Cronin, B	10	20	White, HD	8	19
Saracevic, T	7	11	Jansen, BJ	9	12	Schubert, A	7	11	Hjorland, B	9	17	Saracevic, T	10	20	Vakkari, P	9	18
Schubert, A	7	11	Saracevic, T	9	12	Thelwall, M	7	11	van Leeuwen, TN	9	17	White, HD	10	20	Ford, N	10	17
Egghe, L	8	10	van Leeuwen, TN	9	12	Bar-Ilan, J	8	10	Bar-Ilan, J	10	16	Ford, N	11	19	Hjorland, B	10	17
Huntington, P	8	10	Bar-Ilan, J	10	11	Borgman, C	8	10	Dillon, A	10	16	Vakkari, P	11	19	McCain, K	10	17
Ingwersen, P	8	10	Jarvelin, K	10	11	Egghe, L	8	10	Egghe, L	10	16	Egghe, L	12	18	Ellis, D	11	16
Vaughan, LW	8	10	Meyer, M	10	11	Ellis, D	8	10	McCain, K	10	16	McCain, K	12	18	van Leeuwen, TN	11	16
Cole, C	9	9	Nicholas, D	10	11	Large, A	8	10	Meyer, M	10	16	Bar-Ilan, J	13	17	Bar-Ilan, J	12	15
Ellis, D	9	9	Schubert, A	10	11	Meyer, M	8	10	Saracevic, T	10	16	Ellis, D	13	17	Dillon, A	12	15
Jansen, BJ	9	9	Vakkari, P	10	11	Vaughan, LW	8	10	Schubert, A	10	16	Meyer, M	13	17	Fidel, R	12	15
Jarvelin, K	9	9	Vaughan, LW	10	11	Bates, MJ	9	9	Tenopir, C	10	16	van Leeuwen, TN	13	17	Robertson, S	12	15
Jiang, JJ	9	9	Borgman, C	11	10	Hjorland, B	9	9	Vakkari, P	10	16	Vaughan, LW	13	17	Schubert, A	12	15
Lewison, G	9	9	Ellis, D	11	10	Marchionini, G	9	9	Vaughan, LW	10	16	Dillon, A	14	16	Thelwall, M	12	15
Oppenheim, C	9	9	Huntington, P	11	10	Nicholas, D	9	9	Ellis, D	11	15	Schubert, A	14	16	Vaughan, LW	12	15
Tenopir, C	9	9	Large, A	11	10	Robertson, S	9	9	Nicholas, D	11	15	Bates, MJ	15	15	Bates, MJ	13	14
Vakkari, P	9	9	Lewison, G	11	10	Vakkari, P	9	9	Bates, MJ	12	14	Fidel, R	15	15	Egghe, L	13	14
White, HD	9	9	White, HD	11	10	White, HD	9	9	Huntington, P	12	14	Harnad, S	15	15	Harnad, S	13	14
Wilson, TD	9	9	Bates, MJ	12	9	Dillon, A	10	8	Large, A	12	14	Jarvelin, K	15	15	Meyer, M	13	14
Dillon, A	10	8	Bertot, J	12	9	Fidel, R	10	8	Beheshti, J	13	13	Large, A	15	15	Whittaker, S	13	14
Large, A	10	8	Cole, C	12	9	Harnad, S	10	8	Jarvelin, K	13	13	Nicholas, D	15	15	Case, DO	14	13
Savolainen, R	10	8	Harnad, S	12	9	Hernon, P	10	8	Jiang, JJ	13	13	Robertson, S	15	15	Jarvelin, K	14	13
Williams, P	10	8	Hernon, P	12	9	Jarvelin, K	10	8	Oppenheim, C	13	13	Whittaker, S	15	15	Large, A	14	13
Zitt, M	10	8	Jiang, JJ	12	9	Jiang, JJ	10	8	Lewison, G	14	12	Hernon, P	16	14	Budd, JM	15	12
Bates, MJ	11	7	Marchionini, G	12	9	Kuhlthau, CC	10	8	van Rijsbergen, CJ	14	12	Huntington, P	16	14	Hernon, P	15	12
Beheshti, J	11	7	Oppenheim, C	12	9	Oppenheim, C	10	8	Robertson, S	14	12	Jiang, JJ	16	14	Jiang, JJ	15	12
Borgman, C	11	7	Robertson, S	12	9	Whittaker, S	10	8	Debackere, K	15	11	Oppenheim, C	16	14	Kuhlthau, CC	15	12
Debackere, K	11	7	Whittaker, S	12	9	Belkin, NJ	11	7	Lalmas, M	15	11	Beheshti, J	17	13	Oppenheim, C	15	12
Foo, S	11	7	Williams, P	12	9	Bertot, J	11	7	Marchionini, G	15	11	Case, DO	17	13	van Rijsbergen, CJ	15	12
Garg, KC	11	7	Dillon, A	13	8	Budd, JM	11	7	Savolainen, R	15	11	Lewison, G	17	13	Beheshti, J	16	11
McCain, K	11	7	Fidel, R	13	8	Debackere, K	11	7	Williams, P	15	11	Bertot, J	18	12	Belkin, NJ	16	11
Marchionini, G	11	7	Kuhlthau, CC	13	8	Foo, S	11	7	Yang, CC	15	11	Budd, JM	18	12	Lalmas, M	16	11
Robertson, S	11	7	Lalmas, M	13	8	Huntington, P	11	7	Zitt, M	15	11	Kuhlthau, CC	18	12	Marchionini, G	16	11
Yang, CC	11	7	Losee, RM	13	8	Lalmas, M	11	7	Budd, JM	16	10	Lalmas, M	18	12	Sanderson, M	16	11
Bertot, J	12	6	McCain, K	13	8	Lewison, G	11	7	Cole, C	16	10	Marchionini, G	18	12	Bertot, J	17	10
Budd, JM	12	6	Savolainen, R	13	8	McCain, K	11	7	Foo, S	16	10	van Rijsbergen, CJ	18	12	Davenport, E	17	10

Author	Rank	H(A)	Author	Rank	H(B)	Author	Rank	H(C)	Author	Rank	G(A)	Author	Rank	G(B)	Author	Rank	G(C)
Burrell, QL	12	6	Zitt, M	13	8	Rowley, J	11	7	Jacso, P	16	10	Savolainen, R	18	12	Debackere, K	17	10
De Moya-Anegon, F	12	6	Beheshti, J	14	7	Ruthven, I	11	7	Ruthven, I	16	10	Williams, P	18	12	Larson, RR	17	10
Hernon, P	12	6	Belkin, NJ	14	7	Savolainen, R	11	7	Wilson, C	16	10	Belkin, NJ	19	11	Nicholas, D	17	10
Kretschmer, H	12	6	Budd, JM	14	7	Williams, P	11	7	Bawden, D	17	9	Cole, C	19	11	Ruthven, I	17	10
Lalmas, M	12	6	Burrell, QL	14	7	Zitt, M	11	7	Belkin, NJ	17	9	Debackere, K	19	11	Savolainen, R	17	10
Losee, RM	12	6	Debackere, K	14	7	Beheshti, J	12	6	Davenport, E	17	9	Larson, RR	19	11	Soergel, D	17	10
McClure, CR	12	6	Foo, S	14	7	Buckland, MK	12	6	Kantor, PB	17	9	Losee, RM	19	11	Zitt, M	17	10
van Rijsbergen, CJ	12	6	Garg, KC	14	7	Cole, C	12	6	Losee, RM	17	9	McClure, CR	19	11	Buckland, MK	18	9
Rowlands, I	12	6	McClure, CR	14	7	De Moya-Anegon, F	12	6	Warner, J	17	9	Ruthven, I	19	11	Foo, S	18	9
Ruthven, I	12	6	Rowlands, I	14	7	Jacso, P	12	6	Bertot, J	18	8	Sanderson, M	19	11	Jacso, P	18	9
Warner, J	12	6	Rowley, J	14	7	McClure, CR	12	6	Buckland, MK	18	8	Yang, CC	19	11	Kantor, PB	18	9
Wilson, C	12	6	Ruthven, I	14	7	van Rijsbergen, CJ	12	6	Burrell, QL	18	8	Zitt, M	19	11	Lewison, G	18	9
Bawden, D	13	5	Yang, CC	14	7	Rowlands, I	12	6	Case, DO	18	8	Buckland, MK	20	10	Losee, RM	18	9
Davenport, E	13	5	Bawden, D	15	6	Wildemuth, B	12	6	De Moya-Anegon, F	18	8	Davenport, E	20	10	McClure, CR	18	9
Gupta, BM	13	5	Brophy, P	15	6	Wilson, C	12	6	Garg, KC	18	8	Foo, S	20	10	Rowley, J	18	9
Jacso, P	13	5	Buckland, MK	15	6	Brophy, P	13	5	Hernon, P	18	8	Jacso, P	20	10	Wildemuth, B	18	9
Jamali, HR	13	5	Case, DO	15	6	Burrell, QL	13	5	Kretschmer, H	18	8	Soergel, D	20	10	Wilson, C	18	9
Kantor, PB	13	5	De Moya-Anegon, F	15	6	Case, DO	13	5	McClure, CR	18	8	Warner, J	20	10	Bawden, D	19	8
McKnight, C	13	5	Jacso, P	15	6	Davenport, E	13	5	Morris, A	18	8	Wilson, C	20	10	De Moya-Anegon, F	19	8
Rowley, J	13	5	Kretschmer, H	15	6	Feather, J	13	5	Rowlands, I	18	8	Bawden, D	21	9	Feather, J	19	8
Wildemuth, B	13	5	McKnight, C	15	6	Garg, KC	13	5	Schamber, L	18	8	De Moya-Anegon, F	21	9	Huntington, P	19	8
Belkin, NJ	14	4	Morris, A	15	6	Gupta, BM	13	5	Soergel, D	18	8	Kantor, PB	21	9	Morris, A	19	8
Brophy, P	14	4	van Rijsbergen, CJ	15	6	Jose, JM	13	5	Wildemuth, B	18	8	Morris, A	21	9	Schamber, L	19	8
Buckland, MK	14	4	Van House, N	15	6	Kantor, PB	13	5	Enser, P	19	7	Rowlands, I	21	9	Van House, N	19	8
Case, DO	14	4	Warner, J	15	6	Koenig, MED	13	5	Jose, JM	19	7	Rowley, J	21	9	Warner, J	19	8
Damodaran, L	14	4	Wildemuth, B	15	6	Losee, RM	13	5	Kuhlthau, CC	19	7	Wildemuth, B	21	9	Williams, P	19	8
Dilevko, J	14	4	Wilson, C	15	6	McKnight, C	13	5	McKnight, C	19	7	Brophy, P	22	8	Yang, CC	19	8
Fidel, R	14	4	Davenport, E	16	5	Marcella, R	13	5	Damodaran, L	20	6	Burrell, QL	22	8	Brophy, P	20	7
Gibb, F	14	4	Feather, J	16	5	Morris, A	13	5	Dilevko, J	20	6	Enser, P	22	8	Cole, C	20	7
Gunter, B	14	4	Gupta, BM	16	5	Rowland, F	13	5	Fidel, R	20	6	Feather, J	22	8	Enser, P	20	7
Jose, JM	14	4	Jamali, HR	16	5	Sanderson, M	13	5	Goker, A	20	6	Garg, KC	22	8	Jose, JM	20	7
Larson, RR	14	4	Jose, JM	16	5	Soergel, D	13	5	Gupta, BM	20	6	Jose, JM	22	8	Kretschmer, H	20	7
Marcella, R	14	4	Kantor, PB	16	5	Van House, N	13	5	Jamali, HR	20	6	Kretschmer, H	22	8	McKnight, C	20	7
Morris, A	14	4	Koenig, MED	16	5	Yang, CC	13	5	Larson, RR	20	6	McKnight, C	22	8	Rowland, F	20	7
Ruger, S	14	4	Larson, RR	16	5	Bawden, D	14	4	Marcella, R	20	6	Marcella, R	22	8	Rowlands, I	20	7
Schamber, L	14	4	Marcella, R	16	5	Dilevko, J	14	4	Rowley, J	20	6	Schamber, L	22	8	Burrell, QL	21	6
Soergel, D	14	4	Rowland, F	16	5	Gibb, F	14	4	Ruger, S	20	6	Van House, N	22	8	Damodaran, L	21	6
Enser, P	15	3	Sanderson, M	16	5	Goker, A	14	4	Gibb, F	21	5	Goker, A	23	7	Dilevko, J	21	6
Harnad, S	15	3	Soergel, D	16	5	Kretschmer, H	14	4	Gunter, B	21	5	Koenig, MED	23	7	Goker, A	21	6
Koenig, MED	15	3	Damodaran, L	17	4	Larson, RR	14	4	Harnad, S	21	5	Rowland, F	23	7	Gupta, BM	21	6
Kuhlthau, CC	15	3	Dilevko, J	17	4	Schamber, L	14	4	Koenig, MED	21	5	Damodaran, L	24	6	Koenig, MED	21	6
Liddy, ED	15	3	Gibb, F	17	4	Warner, J	14	4	Rowland, F	21	5	Dilevko, J	24	6	Marcella, R	21	6
Ounis, I	15	3	Goker, A	17	4	Damodaran, L	15	3	Whittaker, S	21	5	Gupta, BM	24	6	Raper, J	21	6
Rowland, F	15	3	Gunter, B	17	4	Enser, P	15	3	Brophy, P	22	4	Jamali, HR	24	6	Garg, KC	22	5
Sanderson, M	15	3	Ruger, S	17	4	Gunter, B	15	3	Ounis, I	22	4	Raper, J	24	6	Gibb, F	23	4
Smith, LC	15	3	Schamber, L	17	4	Jamali, HR	15	3	Sanderson, M	22	4	Ruger, S	24	6	Gunter, B	23	4
Whittaker, S	15	3	Enser, P	18	3	Liddy, ED	15	3	Liddy, ED	23	3	Gibb, F	25	5	Jamali, HR	23	4
Feather, J	16	2	Liddy, ED	18	3	Ounis, I	15	3	Raper, J	23	3	Gunter, B	25	5	Liddy, ED	23	4
Goker, A	16	2	Ounis, I	18	3	Raper, J	15	3	Smith, LC	23	3	Ounis, I	25	5	Ruger, S	23	4
Raper, J	16	2	Raper, J	18	3	Ruger, S	15	3	Van House, N	23	3	Liddy, ED	26	4	Smith, LC	23	4
Tait, J	16	2	Smith, LC	18	3	Smith, LC	15	3	Feather, J	24	2	Smith, LC	26	4	Ounis, I	24	3
Van House, N	16	2	Tait, J	19	2	Tait, J	16	2	Tait, J	24	2	Tait, J	27	2	Tait, J	25	2

Appendix D.

UoA 37 Library and Information Management Spearman Rank Order Correlation Coefficients

			GPA	*h*-Index	*g*-Index	Total citations	Citations/staff	Successive *h*-index	Successive *g*-index
Spearman's rho	GPA	Correlation Coefficient	1.000	.397*	.378*	.403*	.323	.443*	.342
		Sig. (1-tailed)		.038	.046	.035	.077	.022	.065
		N	21	21	21	21	21	21	21

* Correlation is significant at the 0.05 level (1-tailed).

UoA 13 Pharmacy Spearman Rank Order Correlation Coefficients

			GPA	*h*-Index	*g*-Index	Total citations	Citations/staff	Successive *h*-index	Successive *g*-index
Spearman's rho	GPA	Correlation Coefficient	1.000	.772**	.696**	.764**	.735**	.913**	.867**
		Sig. (1-tailed)		.000	.002	.000	.001	.000	.000
		N	15	15	15	15	15	15	15

** Correlation is significant at the 0.01 level (1-tailed).

UoA 42 Anthropology Spearman Rank Order Correlation Coefficients

			GPA	*h*-Index	*g*-Index	Total citations	Citations/staff	Successive *h*-index	Successive *g*-index
Spearman's rho	GPA	Correlation Coefficient	1.000	−.103	−.207	−.271	−.306	−.269	−.272
		Sig. (1-tailed)		.337	.197	.131	.101	.132	.130
		N	19	19	19	19	19	19	19

UoA 42 Anthropology – without Cambridge B Biological anthropology Spearman Rank Order Correlation Coefficients

			GPA	*h*-Index	*g*-Index	Total citations	Citations/staff	Successive *h*-index	Successive *g*-index
Spearman's rho	GPA	Correlation Coefficient	1.000	−.225	−.339	−.401*	−.444*	−.415*	−.413*
		Sig. (1-tailed)		.185	.084	.050	.032	.044	.044
		N	18	18	18	18	18	18	18

* Correlation is significant at the 0.05 level (1-tailed).

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