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The Depth and Breadth of Google Scholar: An Empirical Study

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abstract: The introduction of Google Scholar in November 2004 was accompanied by fanfare, skepticism, and numerous questions about the scope and coverage of this database. Nearly one year after its inception, many of these questions remain unanswered. This study compares the contents of 47 different databases with that of Google Scholar. Included in this investigation are tests for Google Scholar publication date and publication language bias, as well as a study of upload frequency. Tests show Google Scholar's current strengths to be coverage of science and medical databases, open access databases, and single publisher databases. Current weaknesses include lack of coverage of social science and humanities databases and an English language bias.

Introduction

In November 2004, Google officially launched Google Scholar and entered the high-stakes world of research databases.[1] The hype and hubbub surrounding this event were tremendous but understandable, considering the player involved.[2] Google, such a monolithic Internet power, is synonymous in the minds of so many with the Internet. Indeed, one does not find information, one "Googles" it. With this overwhelming name recognition, a large clientele, and a tradition of successful spin-offs such as Froogle and Google Image Search, Google should have little difficulty persuading many to try its new "scholarly paper" search engine.

The current simplicity of Google Scholar, that single search box under the large and now so familiar logo, will attract scholars who are discouraged by the complexity and diversity of the many databases at their disposal. As a number of authors have pointed out, Google Scholar will appeal to researchers who already use Google as part of their information-seeking routine.[3] Google Scholar's specific link resolution, developed by

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Google Scholar and major library vendors, now connects Google Scholar results with the online resources of a researcher's library.[4] Links to library-owned full text should please university researchers and possibly even university librarians. Though only in the beta testing phase of its existence, Google Scholar has attracted significant attention. Whether Google Scholar can maintain a faithful following in the years to come will depend on the ability of this search engine to deliver sufficient quantities of relevant and up-to-date research information.

Despite the growing popularity of Google Scholar, very little is known about the nature of its contents. How often is this database updated? Does Google Scholar have particular disciplinary strengths and weaknesses? How does the content of Google Scholar compare with that of other databases? To gain some insight concerning these mysteries, researchers at the University of Northern Iowa performed a series of empirical tests to gauge the relative coverage of scholarly journal articles by Google Scholar and other well-established databases. This study, conducted during the summer of 2005, compared the contents of 47 databases to Google Scholar. Random samples of database entries were generated for each of the 47 databases, and each entry was tested for coverage within Google Scholar. The databases were grouped into broad disciplines, and the average coverage by Google Scholar of each discipline was then also calculated. Related studies were conducted with the database PsycINFO to measure whether Google Scholar coverage of scholarly literature varied with language of publication or date of publication. Using the databases PubMed and BioMed Central, an additional facet of this project looked at the upload rate of Google Scholar.

Background and Literature Review

What does Google Scholar point to, cover, and index? These questions, as numerous authors have noted, have neither been made clear by Google Scholar nor by its creator Anurag Acharya.[5] In "Google Scholar: A Source for Clinicians?" Jim Henderson lauded Google Scholar for its ability to return ranked results and to provide, free of charge, citation tracking for each of these results. Yet Henderson expressed concerns about Google Scholar's ability to provide up-to-date citations for rapidly evolving medical research and noted a citation bias that favored older literature. Henderson also warned of the inability of Google Scholar to harvest all "deep Web" data found in important health and medical databases such as CINAHL and PsycINFO.[6]

Peter Jacso of the University of Hawaii has conducted the most thorough of the published investigations of Google Scholar to date. Jacso's Web site, side-by-side2 Native Search Engines vs. Google Scholar, allows the curious to simultaneously compare the search engines of the publishers Annual Reviews, Blackwell, Institute of Physics, Nature Publishing Group, and Wiley InterScience with that of Google Scholar on any topic of choice.[7] Jacso lists a number of positives and negatives for this new Google search engine in his many columns on Google Scholar. Google Scholar provides free access to the citations and abstracts of millions of articles, provides a very simple interface, and returns results ranked by relevancy.[8] Jacso suggests that Google Scholar could potentially offer a citation search alternative to Web of Science and Scopus, a real plus for libraries with small and shrinking budgets. However, he points out that currently Google Scholar citation search results are inflated, that Google Scholar includes significant numbers of non-scholarly items, and that the simple search interface that already attracts so many to Google lacks sophisticated search mechanisms, such as journal or author browsing, truncation, and proximity searching, that are often critical to retrieving a specific article. Finally, Jacso notes that, as of mid-April 2005, there was a six-month delay in updates to the Google Scholar database.[9]

Martin Myhill, writing a product review for the *Charleston Advisor* in April 2005, provided the following summary of Google Scholar:

> The vast majority of academic literature is found in the "hidden Web." While Google Scholar has made valiant attempts to include a range of resources in this category, it is apparent that coverage leans heavily on the sciences, rarely includes all the offerings even from partner publishers, and misses many of the quality resources which are more usually accessible to scholars through institutional subscriptions.[10]

Methodology

In contrast to Jacso's comparison of relative yields per search query, this study compared the contents of databases to the contents of Google Scholar. Samples of 50 randomly selected titles were drawn from a given database. An electronic random number generator created by Random.org, http://www.random.org/nform.html, was used to generate all random numbers used in the study. The randomly selected titles were generated using one of the following methods:

1. To select samples from databases that contained records with sequential identification numbers, random numbers were generated from the lowest to the highest record identification number.
2. To select samples for those databases that displayed their entire contents when queried (for example, py>1600 for SilverPlatter databases), random numbers were generated from the lowest to the highest entry value.
3. To select samples from databases that did not display entire contents, did not allow for database record identification searching, and did not contain records with sequential identification numbers, two random numbers from one to 100 were selected and used together in a Boolean "and" keyword search of the database. Random stratified sampling was then deployed to select titles from the results generated by this method.

Whenever possible, database searches were performed while limiting the output of a given database to journal articles or scholarly articles as identified by that database.

Once a random sample of articles had been identified from a given database, the titles from this sample were then individually queried in Google Scholar using the following steps:

1. Titles were entered into Google Scholar as a phrase search (with quotations).
2. If this method failed to produce a hit, punctuation, symbols, formulas, and special scripts were removed, and the remaining segments of the title were searched as phrases (with quotations).

3. If the second step also failed to produce a hit, a title segment and the last name of one or more of the authors were searched.
4. If this too failed, a title segment and the name of the publication were searched.

If steps one or two produced more than 10 results, the Google Scholar search was repeated with the last name of one or more of the authors. If the database record in question contained a non-English title, both the original foreign language title and the English translation provided by the database were searched in Google Scholar. The fraction of sample titles that appeared in Google Scholar was then reported as a percentage of the Google Scholar coverage for that database.

A total of 47 databases covering a variety of subjects was sampled over a four-month period from April through July 2005. Databases were assigned to a discipline category based on the relative relevance to instruction and research conducted within a given college at the University of Northern Iowa. The discipline categories created for this study were business, education, humanities, science and medicine, and social science. Those databases that offered content relevant to multiple colleges and disciplines were assigned to the multidisciplinary category.

Methodology for Publication Date and Publication Language Studies

Related studies were conducted to determine whether Google Scholar coverage of a given database varied by date of publication or by language of publication. The decision was made to choose a database with a high degree of variability in Google Scholar coverage. The researchers at the University of Northern Iowa believed biases in coverage would be most perceptible in databases in which a given record stood roughly a 50-50 chance of appearing in Google Scholar. Thus, PsycINFO was chosen for these studies based on the preliminary 50-item random sample, which showed the Google Scholar coverage of records found in PsycINFO to be 48 percent.

For the publication date study, a random sample of titles from PsycINFO was identified and then searched in Google Scholar for three publication years—2004, 2000, and 1990. Database searches were limited both to the particular publication year and to journal articles. The query *(py=2004) and ((DT:PSYI = JOURNAL) or (DT:PSYI = PEER-REVIEWED-JOURNAL))* was used to generate the population of PsycINFO titles published in 2004, and similar queries were used to generate populations for publication dates 2000 and 1990. Random numbers were generated from one to the value of the largest entry using the random number generator located at Random.org. Four hundred titles were randomly selected for each publication year. Each title was then queried in Google Scholar.

For the publication language study, Google Scholar coverage of PsycINFO articles published in English was compared to coverage of PsycINFO articles published in non-English languages. The query *(py>1700) and ((DT:PSYI = JOURNAL) or (DT:PSYI = PEER-REVIEWED-JOURNAL)) and la=english* was used to generate the population of PsycINFO English language titles. The query *(py>1700) and ((DT:PSYI = JOURNAL) or (DT:PSYI = PEER-REVIEWED-JOURNAL)) not la=english* generated the population of PsycINFO non-English language titles. Random numbers were generated from one to the value of the largest PsycINFO entry using the random number generator located at Random.org. Four hundred English language titles and 400 non-English language titles were then randomly selected from PsycINFO. Each title was then queried in Google Scholar.

Methodology for Google Scholar Upload Frequency Study

From late June through July, studies were also conducted to measure the rate of Google Scholar upload for the databases BioMed Central and PubMed, both chosen based on their high degree of Google Scholar coverage. Initial tests indicated that PubMed appeared to be covered 100 percent by Google Scholar, whereas tests showed Google Scholar coverage of BioMed Central to be 94 percent. Upon further investigation, notable exclusions were found from both these databases for those most recent records that had yet to be loaded in Google Scholar. The information in each of these databases is arrayed quite differently, so for each database a different approach was taken to determine upload frequency.

For BioMed Central, which lists the load date on each item, successive comparisons of BioMed Central with Google Scholar were used to zero in on a "last entry date" for BioMed Central material appearing in Google Scholar. Testing began on June 27, 2005, and at this time no BioMed Central records with a load date after April 1, 2005 were found in Google Scholar. Thus, at the inception of this testing, at least a three-month time lag existed for uploading the information that appeared in BioMed Central Scholar into Google. Regular tests were conducted to monitor Google Scholar coverage for 35 randomly chosen BioMed Central records with load dates ranging from April 2, 2005 to June 21, 2005. Tests to monitor the uploading of these samples into Google Scholar were conducted on June 27, June 30, July 7, July 18, and July 26, 2005.

PubMed assigns each item record a sequential accession number. However, there were no apparent load dates, only publication dates (and many of these dates were somewhat vague, with only the year of publication being listed). Successive approximation was used to determine both the largest (most recent) accession number in PubMed (which was 15981319 on June 28) and the last (most recent) item in PubMed that also appeared in Google Scholar, in this case 15751150, though one outlier, 15751400, out of a sample size of 30 was also shown to be indexed by Google Scholar. Regular tests were also conducted to monitor Google Scholar coverage for the 30 randomly chosen PubMed records ranging from accession number 15751153 to 15790000. Tests to monitor the uploading of these samples into Google Scholar were conducted on June 28, July 7, July 11, July 18, and July 26, 2005.

Results

This study revealed that database content inclusion in Google Scholar varies profoundly from database to database and from discipline to discipline. Great disparities were dis-

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Table 1
Google Scholar Coverage by Database

Business	**52%**
ABI/INFORM Global	52%
Education	**41%**
Education Full Text	40%
ERIC	44%
Library Literature	38%
Humanities	**10%**
Art Abstracts	8%
Historical Abstracts	6%
IIMP	6%
MLA Bibliography	8%
Philosopher's Index	22%
Multidisciplinary	**77%**
Cambridge Journals Online	94%
DOAJ	92%
Emerald Library (MCB)	84%
Expanded Academic ASAP	56%
Highwire Press	94%
Ingenta	82%
JSTOR	30%
Oxford University Press	88%
Project Muse	88%
Sage Journals Online	94%
ScienceDirect (Elsevier)	90%
SPORT Discus	24%
SpringerLink	68%
Synergy (Blackwell)	94%
University of Chicago Press	78%
Wiley InterScience	90%
Science & Medicine	**76%**
ACM Digital Library	100%
AGRICOLA	52%
Applied Science and Technology	74%
Biological Abstracts	74%
Biological and Agricultural Index	88%
BioMed Central	94%
BioOne	84%

Chemical Abstracts	60%
CINAHL	46%
ComDisDOME	100%
GeoRef	26%
MathSciNet	42%
PubMed	100%
PubMed Central	100%
Royal Society of Chemistry	46%
Social Science	**39%**
ATLA Religion Database	10%
Criminal Justice Abstracts	64%
LLBA	40%
PAIS International	26%
PsycInfo	48%
Social Work Abstracts	40%
Sociological Abstracts	44%

covered between Google Scholar's coverage of freely accessible databases and restricted-access databases, between Google Scholar's coverage of single publisher databases and aggregator databases, and between Google Scholar's coverage of databases that offer open access journals and those databases that do not.

Google Scholar coverage of the 47 databases examined in this study ranged from 6 percent (Historical Abstracts and IIMP) to 100 percent (ACM Digital Library, ComDisDOME, PubMed, and PubMed Central). Both the mean and median values of Google Scholar coverage for all databases examined in this study were 60 percent.

Mean scores of Google Scholar database coverage for all databases assigned to a particular discipline category were calculated. These mean discipline category scores were seen to vary from 10 percent in the humanities to 39 percent and 41 percent respectively in social sciences and education and 76 percent in science and medicine. The databases within the multidisciplinary category had a mean Google Scholar coverage score of 77 percent.

The range of Google Scholar coverage scores was greatest for databases within the science and medicine and social science discipline categories. For the 18 databases within the science and medicine discipline, category coverage by Google Scholar ranged from 26 percent for GeoRef to 100 percent for ACM Digital Library, ComDisDOME, PubMed, and PubMed Central. For the seven databases within the social sciences discipline category, Google Scholar coverage scores ran from 10 percent for ATLA Religion Database to 64 percent for Criminal Justice Abstracts. For the five databases within the humanities discipline category, Google Scholar coverage scores ranged from 6 percent for Historical Abstracts to 22 percent for Philosopher's Index. For the three databases within the education discipline category, Google Scholar coverage ranged from 38 percent for Library Literature to 40 percent for Education Full Text and to 44 percent for the ERIC database. For the majority of multidisciplinary databases, Google Scholar provided

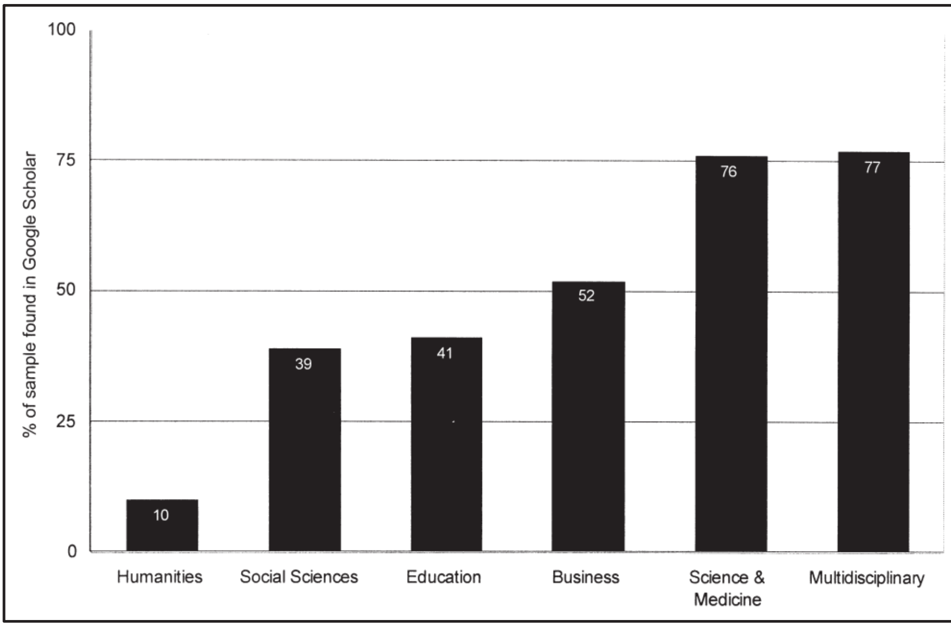

Figure 1. Google Scholar Coverage by Discipline

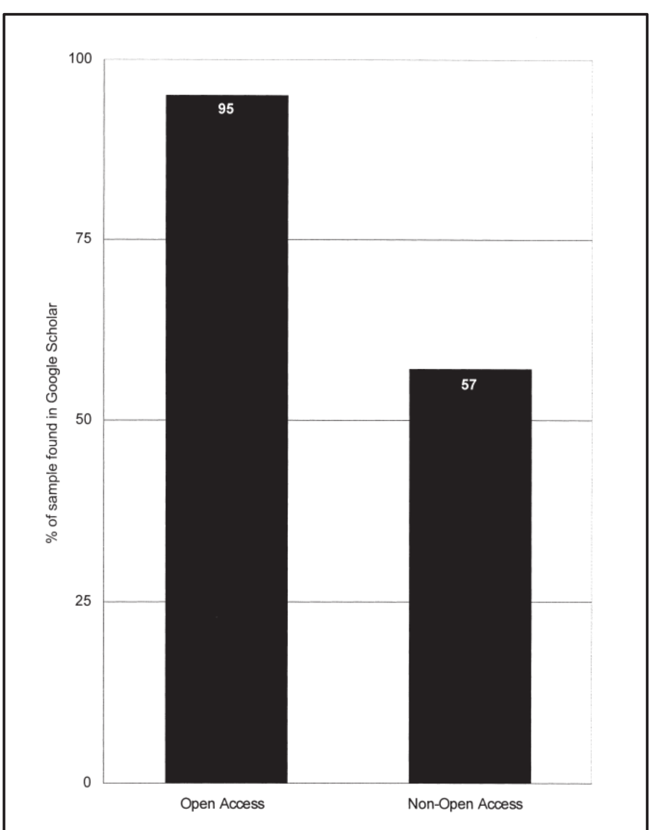

Figure 2. Google Scholar Coverage of Databases, Open Access versus Non-Open Access Journals

coverage for 80 percent or more of the databases, the exceptions being 68 percent for SpringerLink, 58 percent for Expanded Academic ASAP, 30 percent for JSTOR, and 24 percent for SPORT Discus.

Databases in this study that provide open access journals, namely DOAJ, BioMed Central, Highwire Press, and PubMed Central, all appeared to be well covered by Google Scholar. Indeed the discrepancy between coverage of open access journal databases and all other databases in this study was quite pronounced, with the mean score for Google Scholar coverage of open access journal databases being 95 percent and the mean score for all other databases being 57 percent.

This study would indicate that currently Google Scholar provides thorough coverage of single publisher databases. In contrast, Google Scholar provides much less coverage of index and aggregator databases, many of which are not freely accessible. Google Scholar's coverage of the "free" Internet is markedly superior to coverage of restricted or fee-based Internet resources. Twenty-one of the databases studied were "free" Internet resources available to the general public. The mean score for Google Scholar coverage of these freely accessible databases was 84 percent. In contrast, for the other 26 restricted access databases, the mean score was 41 percent; and this score would have been only 39 percent if the database ComDisDOME, a restricted access database whose journal article content appears to be primarily a subset of PubMed, were removed from this calculation.

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Google Scholar, PsycINFO, and Foreign Language Bias

Results from the PsycINFO publication language study showed that, currently, Google Scholar has a pronounced bias toward English language publications. Google Scholar coverage of PsycINFO, in general, was 48 percent; Google Scholar coverage of English only PsycINFO titles was 68 percent, whereas Google Scholar coverage of non-English PsycINFO titles was only12 percent.

Google Scholar, PsycINFO, and Publication Date Bias

A publication date bias in Google Scholar coverage of articles found in the PsycINFO database was also apparent. Google Scholar coverage of PsycINFO for all publication dates was 48 percent, yet Google Scholar coverage of PsycINFO was 60 percent for titles published in 1990, 83 percent for titles published in 2000, and 78 percent for titles published in 2004. When data were pooled from the PsycINFO English-only study, 48 percent of the 92 samples from years 1960 to 1980 was covered by Google Scholar, and Google Scholar indexed only 20 percent of the 50 samples from pre-1960 PsycINFO English-only samples.

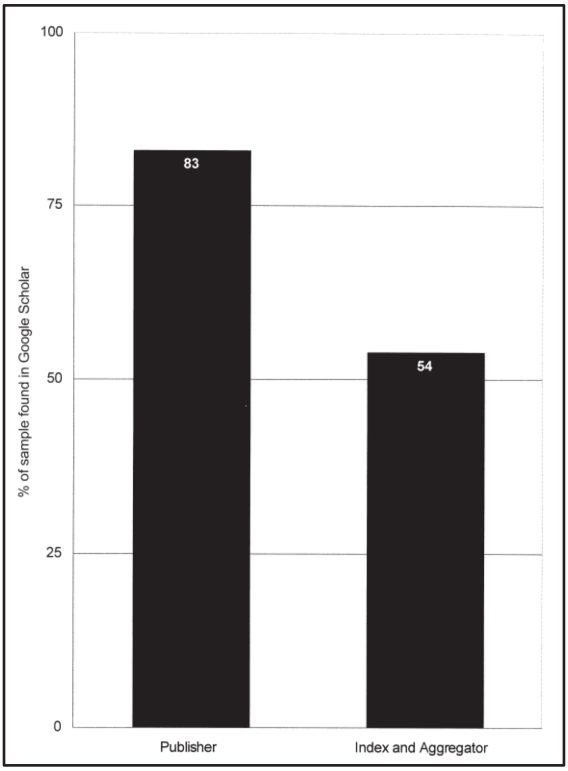

Figure 3. Google Scholar Coverage of Databases, Publisher versus Index and Aggregator

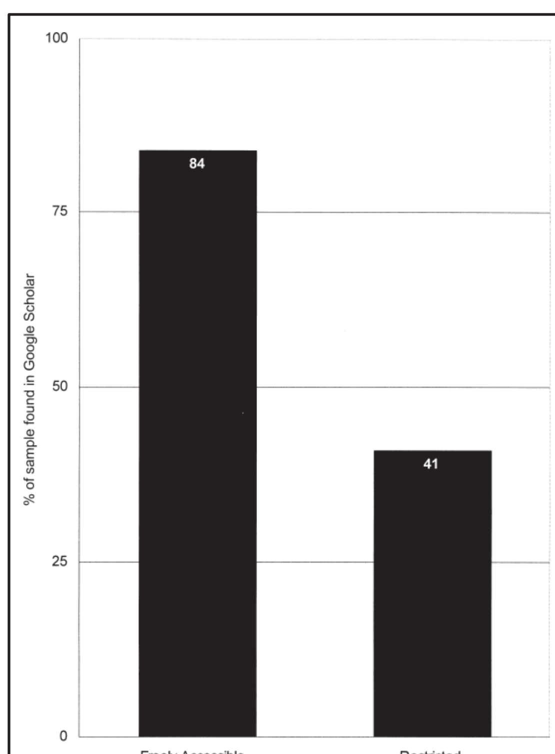

Figure 4. Google Scholar Coverage of Databases, Freely Accessible versus Restricted

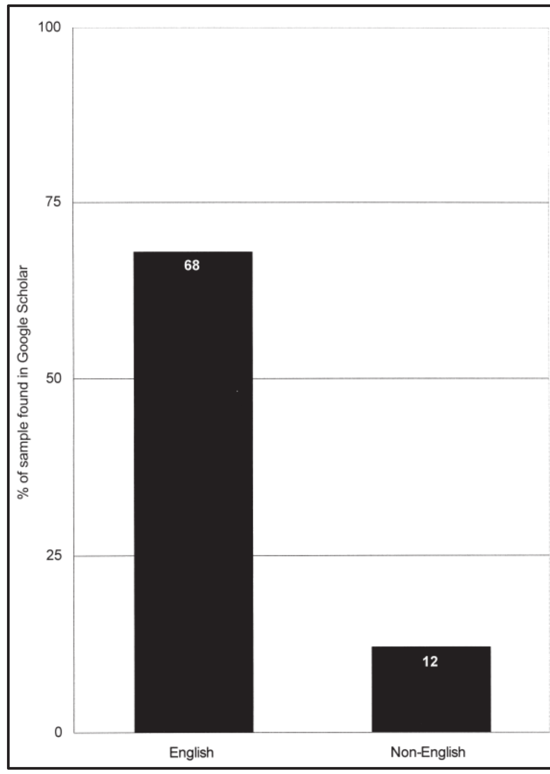

Figure 5. Google Scholar Coverage of PsycINFO by Language

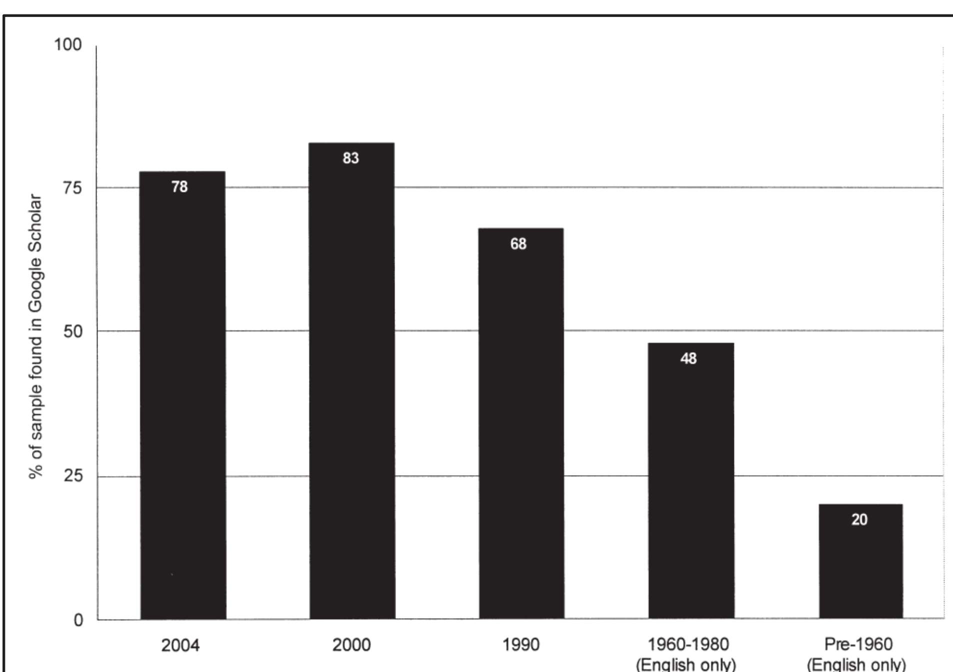

Figure 6. Google Scholar of PsycINFO by Publication Date

Upload Testing of Google Scholar

As noted previously in the methodology, no BioMed Central records with a load date after April 1, 2005 were found in Google Scholar at the inception of testing on June 27, 2005. A set of 35 titles was randomly selected in BioMed Central from a group of titles not yet appearing in Google Scholar on June 27. This set of 35 titles was again checked against Google Scholar on June 30, July 7, and July 18, but none of these titles were retrieved. Thus, a 12-week delay in uploading of new information grew to a maximum of roughly 15 weeks before there was evidence of uploading activity between July 18 and July 26, 2005. By July 26, 34 of the 35 titles first sampled on June 27 were retrievable from Google Scholar.

Monitoring of Google Scholar updates for PubMed titles began on June 28 with PubMed offering titles with accession numbers as high as 15981319, whereas Google Scholar offered PubMed titles with accession numbers as high as 15751150. A set of 30 titles was randomly selected from PubMed from a group of titles not yet appearing in Google Scholar on June 28. Assuming that there were few gaps in the PubMed accession number sequence at the time of testing on June 28, 2005, there could have been as many as 230,000 records (1.4 percent of the PubMed database) not yet uploaded into Google Scholar. This disparity between PubMed titles and Google Scholar posting of PubMed titles grew to roughly 245,000 records by testing date July 7 and to roughly 270,000 by July 18, 2005. As with BioMed Central, sometime between the July 18 and July 26 test dates additional PubMed titles were added to Google Scholar. On July 26, 2005, 27 of the 30 randomly sampled titles were retrievable from Google Scholar.

Discussion

The tests conducted in this study revealed a number of specific strengths and weaknesses with the search engine Google Scholar in its current beta test phase. Coverage of open access journals, freely accessible databases, and single publisher databases is very strong.

Google Scholar coverage of databases in the humanities and fine arts is quite poor. Coverage of databases in the social sciences, education, and business is somewhat hit-or-miss, with roughly 50 percent of the content in these databases indexed by Google Scholar. A particular strength of Google Scholar appears to be its coverage of scientific and medical literature. This might reflect an intended emphasis on the part of Google Scholar, or perhaps this strong showing is simply the by-product of a preponderance of freely accessible records of scientific and medical research.

Although Google Scholar testing demonstrated strong coverage of literature in the science and medicine category, there were some notable exceptions.

Although Google Scholar testing demonstrated strong coverage of literature in the science and medicine category, there were some notable exceptions. Google Scholar only covered 26 percent of GeoRef, 42 percent of MathSciNet, 46 percent of CINAHL, 46 percent of Royal Society of Chemistry, and 52 percent of AGRICOLA. Nonetheless, the perception that Google Scholar is a scientific literature database is further enhanced by Google Scholar coverage of databases designated as multidisciplinary. Many of the databases in the multidisciplinary category are primarily, though not exclusively, science databases, namely Cambridge Journals, DOAJ, Ingenta, Oxford University Press, ScienceDirect, SpringerLink, and Wiley InterScience. Coverage by Google Scholar of these science-rich multidisciplinary databases alone was 86 percent. Google Scholar gleans much less content from those multidisciplinary databases that were less focused on science. Google Scholar only contained 24 percent of SPORT Discus, 30 percent of JSTOR, and 56 percent of Expanded Academic ASAP.

What do the results from this study of Google Scholar mean for both researchers and information professionals? For those who enjoy a relative wealth of commercial databases, this is a cautionary tale. Google Scholar is not yet the tool of choice for research in the humanities, education, business, and social sciences. Coverage is poor to spotty within these fields of research. Coverage of non-English literature is weak. Older material may well be missed, and the most current information is slow to arrive on Google Scholar's doorstep. Still, Google Scholar does provide a possible alternative for unified searching of scientific and medical literature with hyperlinks to the full text owned by well-endowed institutions. For those who languish in more information-poor environments, Google Scholar is a most welcome arrival, provided one understands English. Coverage of less than 50 percent of a database is still preferable to no database access at all, and occasionally Google Scholar hyperlinks do lead to full-text articles provided by open access journals.

Future Studies

Google Scholar could render future studies such as this both unnecessary and obsolete, simply by sharing a detailed description of its content collection methodology. Should such information be some time in coming, the authors suggest a number of follow up studies to further define the behavior and attributes of Google Scholar. The rate of Google Scholar uploading, barely touched upon in this study, could be monitored in greater depth and breadth and for a much longer duration. The capabilities of the Google Scholar advanced search option should be tested and analyzed. The strengths and limitations of the Google Scholar linking services to full text could be considered. Studies of the "cited by" feature of Google Scholar and comparisons of this feature to citation services offered by Web of Knowledge and Scopus would be most welcome. Finally, a better understanding of the information gathering behavior of researchers is vital to further discussions of Google Scholar and any other database. Surveys and studies that measure the attitudes and research behaviors of established scholars and college students with respect to Google Scholar would be of great utility to both database designers and information professionals.

Conclusion

The idiosyncrasies of Google Scholar that were exposed as a result of this study should be considered with the acknowledgment that this database is still in a beta test mode. Whatever weaknesses and strengths Google Scholar now possesses will undoubtedly change as this scholarly search engine develops in the years to come. That said, many researchers are now, or will soon be, regular users of Google Scholar, beta test notwithstanding, just as they are now regular users of Google.[11] If scholars intend to use Google Scholar, whether due to name recognition, the facile search interface, the freely available "cited by" feature, or simply the lack of alternatives, they should understand this search engine's strengths and limitations. If information professionals intend to use, recommend, and advertise Google Scholar, they, too, must be aware of the scope and capabilities of this search engine.

This study focused on Google Scholar content and not on the capabilities and functionality of the Google Scholar search engine. Google Scholar may well contain a given record, indeed it may contain multiple variants of the same record, but Google Scholar will only succeed if it can make its records both easy to find and easy to retrieve. Yet even within this first year of its inception, Google Scholar already freely offers researchers and libraries a database with great breadth and, within the fields of science and medicine, respectable depth. Though not without flaws, this database provides a free "cited by" service with citation counts and hyperlinks to the citing references. Google Scholar is working with libraries and library vendors to connect Google Scholar search results to library-owned full text. Google Scholar offers a simple search interface that will, despite its shortcomings, appeal to many researchers. Google Scholar will be a database to monitor, to study, and with which to reckon.

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