

# The coverage of Microsoft Academic: Analyzing the publication output of a university

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**Abstract** This is the first detailed study on the coverage of Microsoft Academic (MA). Based on the complete and verified publication list of a university, the coverage of MA was assessed and compared with two benchmark databases, Scopus and Web of Science (WoS), on the level of individual publications. Citation counts were analyzed and issues related to data retrieval and data quality were examined. A Perl script was written to retrieve metadata from MA. We find that MA covers journal articles, working papers, and conference items to a substantial extent. MA surpasses Scopus and WoS clearly with respect to book-related document types and conference items but falls slightly behind Scopus with regard to journal articles. MA shows the same biases as Scopus and WoS with regard to the coverage of the social sciences and humanities, non-English publications, and open-access publications. Rank correlations of citation counts are high between MA and the benchmark databases. We find that the publication year is correct for 89.5% of all publications and the number of authors for 95.1% of the journal articles. Given the fast and ongoing development of MA, we conclude that MA is on the verge of becoming a bibliometric superpower. However, comprehensive studies on the quality of MA data are still lacking.

**Keywords** coverage, research fields, publication language, Microsoft Academic, Scopus, Web of Science, Eprints, citation analysis

## Introduction

Microsoft Academic Graph (MAG) was established in June 2015 (Microsoft, 2017) and models “the real-life academic communication activities as a heterogeneous graph” (Sinha et al., 2015, p. 244). MAG data can either be accessed by using the Microsoft Academic search engine<sup>1</sup> or by employing the Academic Knowledge API (AK API)<sup>2</sup>. We refer to these services

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<sup>1</sup> <http://academic.research.microsoft.com>

<sup>2</sup> <https://www.microsoft.com/cognitive-services/en-us/academic-knowledge-api>

and to the constituents of these services as Microsoft Academic (MA). MA is evolving quickly and several new features have been implemented since our first examination of the AK API (Hug, Ochsner, & Brändle, 2017). For example, social media features have been integrated as well as a new method, Graph Search, which allows searching for graph patterns in MAG. Furthermore, aggregated citation counts for authors, institutions, fields, journals, and conferences have been added. Most interestingly, citation contexts of references are now retrievable, enabling the calculation of advanced indicators suggested by Waltman (2016) and paving the way for the study of citation acts (Bertin, 2008; Bertin, Atanassova, Sugimoto, & Lariviere, 2016). MA is also evolving quickly in terms of coverage. According to the developer team of MA, the database expanded from 83 million records in 2015 (Sinha et al., 2015), to 140 million in 2016 (Wade, Wang, Sun, & Gulli, 2016), and to 168 million in early 2017 (A. Chen, personal communication, March 31, 2017).

The predecessor of MA, Microsoft Academic Search (MAS), has been decommissioned towards the end of 2016 and has attracted little bibliometric research. In particular, Harzing (2016) identified only six journal articles related to MAS and bibliometrics. In contrast, MA has already spurred great interest in a short period of time and triggered several studies that focus on bibliometric topics. There are four studies on visualization and mapping (De Domenico, Omodei, & Arenas, 2016; Portenoy, Hullman, & West, 2016; Portenoy, & West, 2017, Tan et al., 2016). Furthermore, there are eleven studies that deal with the development of indicators and algorithms (Effendy & Yap, 2016; Effendy & Yap, 2017; Herrmannova & Knoth, 2016b; Luo, Gong, Hu, Duan, & Ma, 2016; Medo & Cimini, 2016; Ribas, Ueda, Santos, Ribeiro-Neto, & Ziviani, 2016; Sandulescu & Chiru, 2016; Wesley-Smith, Bergstrom, & West, 2016; Vaccario, Medo, Wider, & Mariani, 2017; Wilson, Mohan, Arif, Chaudhury, & Lall, 2016; Xiao et al., 2016). Last but not least, there are four studies that assess the potential of MA for evaluative bibliometrics. Hug et al. (2017) examined the strengths and weaknesses of the AK API from the perspective of bibliometrics and calculated normalized indicators (i.e. average-based and distribution-based indicators). Harzing (2016) and Harzing and Alakangas (2017) compared publication and citation coverage of MA with Scopus, the Web of Science (WoS), and Google Scholar (GS). Herrmannova and Knoth (2016a) compared features of the metadata stored in MAG, Mendeley, and Connecting Repositories (CORE). They also compared rankings of universities and journals based on MAG data with the Scimago Journal & Country Rank and the Webometrics Ranking of World Universities.

In evaluative bibliometrics, it is crucial to know how well a given database covers publications in order to decide whether it is appropriate and valid for citation analysis (Mongeon & Paul-Hus, 2016). In the studies of Harzing (2016), Harzing and Alakangas (2017), and Herrmannova and Knoth (2016a), the publication coverage of MA was addressed but the results are inconclusive for two reasons. First, the studies provide little empirical evidence, since one study analyzed a very small sample size (Harzing, 2016) and the two large-scale studies did not investigate publication coverage in detail (Harzing & Alakangas, 2017; Herrmannova & Knoth, 2016a). The large-scale studies can be summarized as follows with regard to publication coverage. Harzing and Alakangas (2017) calculated the average number of papers of 145 academics in MA, Scopus, WoS, and GS. They found that, on average, MA reports more papers per academic (137) than Scopus (96) and WoS (96) and less than GS (155). They provided no further information on publication coverage. From a methodological perspective, the study has two shortcomings. On the one hand, publications were collected based on author queries and not on the level of individual papers, as required by Moed (2005). On the other hand, Moed (2005, p. 77) claims that “lists [based on author queries] are preliminary and need further verification”. However, no such verification was conducted by Harzing and Alakangas (2017). Herrmannova and Knoth (2016a) analyzed the number of DOIs stored in MA, Mendeley, and CORE and found that there are 35,5 Mio. unique DOIs in MA. They also analyzed the number of publications assigned to the different fields in MA. However, according to Hug et al. (2017), raw field information from MA cannot readily be used for bibliometric analyses. Second, in all three studies, the coverage was analyzed in relation to other databases. Hence, these studies did not assess how well actual publication lists of scholars, institutes, or universities are represented in MA. Put differently, there are no studies on the recall of an actual publication list, where recall is defined as the fraction of relevant documents that are retrieved (Manning, Raghavan, & Schütze, 2008). Therefore, the main goal of the present study is to assess the publication coverage of MA in relation to an actual publication list. In particular, we will analyze the coverage of a verified publication list of a university in MA and in two benchmark databases (Scopus and WoS) on the level of individual publications. In addition, we will analyze citation counts and examine issues related to data retrieval and data quality. The following research questions will be addressed. What is the coverage of the publication list in MA, Scopus, and WoS with regard to the document type, the publication language, the access status (open or restricted), the publication year, and the research field? What are the citations per publication in MA, Scopus, and WoS and what is the share of uncited publications per

database? How do citation counts of publications correlate between the three databases? How do the different modes of retrieving data from MA perform (recall, precision)? What is the quality of the metadata in MA with respect to DOI coverage, number of authors per paper, and publication year?

The remainder of the article is organized as follows. The Methods section is organized in two parts. In the first part, the Zurich Open Archive and Repository (ZORA) is described, from which the publications for this study are drawn. This includes information about ZORA in general, the definition of the publication lists (i.e. ZORA<sup>total</sup> and ZORA<sup>2008-2015</sup>), specifications of the repository software, and a description of data harvesting from the benchmark databases (Scopus and WoS). In the second part, a Perl script is specified, which retrieves metadata of ZORA items from MA in two modes (i.e. title\_exact and title\_word) and evaluates the matching quality of the retrieved data. In the Results sections, the performance of the Perl script with respect to retrieval and matching quality, the evaluation of MA metadata, the assessment of the coverage, and the analysis of citation counts are presented. Finally, the results are discussed and a conclusion is provided.

## **Method**

### **Zurich Open Archive and Repository (ZORA)**

The publications for the present study are drawn from ZORA<sup>3</sup>, an open archive and repository in which the University of Zurich (UZH) documents its publication output. The UZH covers all disciplines and to a very limited extent also engineering. ZORA was established in 2006 and since 2008, the UZH requires their researchers to deposit metadata of their publications in ZORA, including full texts whenever possible. Researchers feed their publications into the repository and then, according to the ZORA regulations (Main Library of the University of Zurich, 2017), “all publications are checked and completed by the ZORA editorial team in accordance with the faculties. The focus of this works is on the quality of bibliographic data [...] and on the copyright situation.” For example, the editorial team compares the publication year of a submitted record with the original publication and items published online first are checked automatically in Crossref on a daily basis. The repository thus meets one of the requirements for evaluative bibliometrics devised by Moed (2005), who considers compiling a complete and verified publication list on the level of individual publications a crucial first step. When data for the present study was collected in October 2016, ZORA contained a total

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<sup>3</sup> <https://www.zora.uzh.ch>

of 91'215 items. We refer to this publication list as ZORA<sup>total</sup>. In addition to the usual bibliographic data, the metadata in ZORA also includes further information, such as publication language, access status (open or restricted), affiliation to UZH institutes/clinics, and document type. These four variables plus the publication year are used to analyze the coverage of the publication list in MA, Scopus, and WoS.

For the purpose of comparing MA, Scopus, and WoS, we restrict our analysis to a subset of ZORA<sup>total</sup>. We refer to this restricted set as ZORA<sup>2008-2015</sup>. It comprises 62'791 items and differs in three ways from ZORA<sup>total</sup>. First, it encompasses the publication years 2008 to 2015, since data entry in ZORA is mandatory only for publications since 2008 and because data collection and verification of the publication year 2016 will only be finished in 2017. Second, only publications from researchers at institutes and clinics are included, since researchers at other organizational units of the UZH (e.g. competence centers, research priority programs) are not required to feed their publications into the repository. Third, only common document types are included (i.e. journal articles, conference items, monographs, book sections, edited volumes) because ZORA features types which are specific to ZORA and/or belong to grey literature (i.e. dissertations, habilitations, newspaper articles, published research reports, working papers, and publications in electronic form). These latter document types are not covered by the benchmark databases (see Clarivate, 2017; Elsevier, 2017) and would thus distort the comparison of MA, Scopus, and WoS.

ZORA is based on the open source EPrints repository software (version 3.3)<sup>4</sup>, a web-based repository that requires an Apache webserver, MySQL and Perl and belongs to the three most popular institutional repository platforms. For relevance ranked searches, the UZH incarnation runs the Xapian search engine as an add-on. Plug-ins and scripts extend the standard EPrints functionality of ZORA. Scopus citation counts are harvested using the Citation count dataset and import plug-in developed by the Queensland University of Technology<sup>5</sup> and modified by the UZH. This plug-in queries the Scopus API<sup>6</sup> sequentially - first with Scopus EID and second with the DOI for any document type, followed by PubMed ID, ISBN, and bibliographic metadata for journal articles, book sections, conference items, monographs, and edited volumes. Daily batches of ZORA item data (about 3'000 items) are sent in order for all items to be processed once per month. WoS citation counts are harvested

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<sup>4</sup> <http://www.eprints.org/>

<sup>5</sup> <https://github.com/QUTlib/citation-import>

<sup>6</sup> <http://api.elsevier.com/content/search/scopus>

using a script developed at the UZH that accesses WoS via the Link Article Match Retrieval API<sup>7</sup>. This script sends queries for the five document types mentioned above by using WoS UT number, DOI, PubMed ID, ISBN, and bibliographic metadata. All ZORA items are processed once per week.

### **Perl script for retrieving and matching Microsoft Academic data**

The AK API offers four REST endpoints to access MAG data.<sup>8</sup> For this study, the *Evaluate* endpoint was used, which retrieves metadata of publications (called ‘entity attributes’ in MA) from MAG based on a query expression.<sup>9</sup> An *Evaluate* request returns one or several items that match the query expression. In the present study, the maximum number of items that could be returned per query was limited to 10. The AK API assigns to each returned item a natural log probability value to indicate the quality of the match and, by default, ranks the returned items by descending probability in the result set. To build query expressions we used information from the title of ZORA items since DOIs cannot be used in query expressions (Hug et al., 2017). A Perl script (`academic_search`) was written, which relies on the *Evaluate* method to query MAG with data from an EPrints repository, saves the JSON results, evaluates whether the results sent by the AK API match the ZORA item (see below), and creates reports in XML and CSV formats. The script allows four different retrieval modes, of which the following two are relevant for this study: `title_words` and `title_exact`.

The `title_words` (`ti_wo`) mode takes a stop-word filtered list of title words from the ZORA Xapian index and constructs an AND-nested query expression using the MA entity attribute ‘W’ (W = words from paper title/abstract for full text search). For example, the query expression of the record with the title “HEE-GER: a systematic review of German economic evaluations of health care published 1990-2004” is constructed as: `And(And(And(And(And(And(And(And(And(W='care',W='economic'),W='evaluations'),W='ger'),W='german'),W='health'),W='hee'),W='published'),W='review'),W='systematic')`. The `ti_wo` mode applies a list of about 1’500 stop words in English, German, French, Italian, and Spanish, including stop words that were supplied by the developer team of MA (D. Eide, personal communication, October 10, 2016). It further filters out numbers. Since the query expression uses the apostrophe as delimiter, the `ti_wo` mode takes as query word only the part

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<sup>7</sup> <http://ips-science-help.thomsonreuters.com/LAMRService/WebServicesOverviewGroup/overview.html>

<sup>8</sup> For an overview of the REST endpoints see <https://www.microsoft.com/cognitive-services/en-us/Academic-Knowledge-API/documentation/overview>

<sup>9</sup> For a detailed description of the Evaluate method see <https://www.microsoft.com/cognitive-services/en-us/Academic-Knowledge-API/documentation/EvaluateMethod>

before or after the apostrophe if the index term from Xpian contains one. It takes the longer part of the string.

The `title_exact` (`ti_ex`) mode creates an exact title query from the publication title stored in ZORA by transforming the title to lowercase, filtering out special characters, and removing superfluous whitespace. The query expression uses the MA entity attribute 'Ti' (Ti = paper title) and, taking the item above as an example, is constructed as: `Ti='hee ger a systematic review of german economic evaluations of health care published 1990 2004'`. The performance of the two retrieval modes will be assessed from the perspective of recall, precision, and the  $F_1$  score. Recall (R) is defined as the fraction of relevant documents that are retrieved, precision (P) as the fraction of retrieved documents that are relevant, and the  $F_1$  score as the harmonic mean of precision and recall (Manning et al., 2008).

The Perl script allows to process the whole publication set of an EPrints repository or to specify individual publications by their EPrint IDs. Furthermore, there is a restart option that renders it possible to continue querying the AK API at the point where the script was interrupted. Mapping of institutes and clinics to research fields is performed by a CSV file read by the script. The query parameters can be configured in a configuration file. The following parameters were used: `count=10` (the max. number of items returned by the AK API per query), `model=latest`, `offset=0`. The returned items were ranked by descending probability (default setting in the AK API). The following MA entity attributes were retrieved: `Id`, `Ti`, `Y`, `D`, `CC`, `ECC`, `AA.AuN`, `AA.AuId`, `AA.AfN`, `AA.AfId`, `F.FN`, `F.FId`, `J.JN`, `J.JId`, `C.CN`, `C.CId`, `RId`, and the extended metadata attributes `E`, which among other things contain the DOI.<sup>10</sup> The Perl script and its associated files are available on GitHub.<sup>11</sup> After having received the data from the AK API, the algorithm evaluates each returned item by comparing MA entity attributes with ZORA metadata. A returned item is considered a match if at least one of the following three match types apply. *doi*: DOI in MA and ZORA are equal. *title*: the cleaned title string from the `ti_ex` mode is identical to the MA title. *bib*: bibliographic data (journal title, volume, issue, first page) is identical. The algorithm then selects the returned item with the most reliable match based on the following priority to determine the 'matched items': *doi* is considered to be most reliable to determine a matched item due to the uniqueness of the DOI, *title* is considered to be less reliable, and *bib* the least reliable. After

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<sup>10</sup> For a description of the entity attributes see <https://www.microsoft.com/cognitive-services/en-us/Academic-Knowledge-API/documentation/EntityAttributes>

<sup>11</sup> <https://github.com/eprintsug/microsoft-academic>

selecting the most reliable matches, the parsed MA and ZORA field data is stored together with the following two variables: the rank of the matched item in the AK API result set (1-10) and the match type of the matched item (*doi*, *title*, *bib*). These variables are employed to assess the matching quality of ZORA and MA data as well as to assess the performance of the retrieval modes.

## Results

### Performance of the retrieval modes

#### *Recall, precision, and F<sub>1</sub> score*

While 49.7% of the items from ZORA<sup>total</sup> were retrieved from MA both with the *ti\_ex* and *ti\_wo* mode (i.e. 45'378 items), 1.4% could be retrieved with the *ti\_ex* mode only (i.e. 1'319 items) and 1.7% with the *ti\_wo* mode only (i.e. 1'534 items). Hence, recall of the *ti\_ex* mode is slightly lower (51.2%) than for the *ti\_wo* mode (51.4%; see Table 1). The combination of the results of the two modes yields an overall recall of 52.9% (48'231 items). The precision was calculated by dividing the sum of matched items by the sum of returned items (see Table 1). Since a maximum of 10 items was returned per query, the precision scores represent upper estimates. The precision of the *ti\_ex* mode (0.897) is considerably higher than the precision of the *ti\_wo* mode (0.703). For 922 items retrieved by both the *ti\_ex* and *ti\_wo* mode, multiple MA IDs were obtained (see Table 2). These items represent most likely false positives and, hence, were subtracted from the matched items. Based on the corrected matched items, a corrected precision was calculated, which is 0.879 for *ti\_ex* and 0.689 for *ti\_wo* (see Table 1). Based on recall and the corrected precision, the F<sub>1</sub> score was calculated, which yields a score of 0.647 for the *ti\_ex* mode and 0.594 for the *ti\_wo* mode.

Table 1 Recall and precision of the retrieval modes *title\_exact* and *title\_word* based on ZORA<sup>total</sup>

Retrieval mode	Matched items	Corrected matched items	Returned items	R	P	P corrected	F <sub>1</sub> corrected
<i>ti_ex</i>	46'697	45'775	52'067	0.512	0.897	0.879	0.647
<i>ti_wo</i>	46'912	45'990	66'771	0.514	0.703	0.689	0.594
Combined	48'231	47'309	59'419 <sup>a</sup>	0.529	0.812	0.796	0.641

*Note:* R = recall (in % of ZORA<sup>total</sup>). P = precision (in % of returned items). *ti\_ex* = retrieval mode *title\_exact*. *ti\_wo* = retrieval mode *title\_word*. Values for P and P corrected represent upper estimates since a maximum of 10 items could be returned per query. a = average of returned items by *ti\_ex* and *ti\_wo*.

### Rank in the AK API result set

Almost all matched items rank in the top three in the result set of the AK API (ti\_ex: 99.4% of the matched items; ti\_wo: 98.4%). The ti\_ex mode is slightly more precise than the ti\_wo mode as the share of matched items on the first place in the result set of the AK API reveals (95.8% vs. 92.5%).

### Performance of the matching algorithm

Of the matched items ( $n = 48'231$ ), 69.9% were matched by *doi*, 29.7% by *title*, and 0.4% by *bib*. To assess the precision of the matching algorithm in the Perl script, the differences in the results, which were both retrieved by the ti\_ex and the ti\_wo mode ( $n = 45'378$ ), were exploited. We assume that if a ZORA item gets the same MA ID by the ti\_ex and ti\_wo mode, the matching algorithm has selected the correct item. As can be seen in Table 2, this is the case for 98% of the matched items. However, 911 of the matched items (2%) have different MA IDs and, hence, represent most likely false positives. Of the 511 items that were selected by the same match type but returned different MA IDs (see Table 2), 280 items were matched by *doi* and 231 were matched by *title*. While it is probable that there are publications that have the exact same title, the items matched by *doi* seem to indicate duplicate records in MA. Inspection of some of the 280 items matched by *doi* indeed revealed that the publications were the same but with slight variations in the MA title. Given that 29'586 items were matched by *doi* in both retrieval modes, the share of false positive DOI matches in our analysis is 0.9% (i.e. 280 of 29'586 items).

Table 2 Differences and commonalities between the retrieval modes title\_exact and title\_word regarding MA ID and match type based on ZORA<sup>total</sup>

Match type	MA ID			
	Same in ti_ex and ti_wo		Different in ti_ex and ti_wo	
	No.	%	No.	%
Same in ti_ex and ti_wo	40'588	89.4	511	1.1
Different in ti_ex and ti_wo	3'898	8.6	411	0.9
Total	44'456	98.0	922	2.0

Note: ti\_ex = retrieval mode title\_exact. ti\_wo = retrieval mode title\_word. % = in % of items retrieved by both the modes ti\_ex and ti\_wo ( $n = 45'378$  items).

## Quality of Microsoft Academic metadata

### *Publication year*

Comparing the publication years of the matched items ( $n = 48'231$ ) between MA and ZORA reveals that 89.5% of the items have identical publication years, 7.0% differ by  $\pm 1$  year (+1 year in MA: 2.1%; -1 year: 4.9%), and 3.5% feature larger differences ( $> +1$  year: 1.7%;  $< -1$  year: 1.8%). Publication years of the matched items range from 1966 to 2017 in ZORA<sup>total</sup> and from 1866 to 2017 in MA. Differences are distributed equally among publication years, which means that they do not originate predominantly from the most recent publications.

### *Number of authors*

Comparing the number of authors of the matched journal articles ( $n = 42'201$ ) between MA and ZORA shows that 95.1% of the articles have identical author numbers, 1.7% differ by  $\pm 1$  author (+1 author in MA: 1.0%; -1 author: 0.7%), and 3.2% feature larger differences ( $> +1$  author: 2.4%;  $< -1$  author: 0.8%). The number of authors of further publication types could not be analyzed, as ZORA only provides reliable author counts for journal articles.

### *DOI*

51.6% of the items in ZORA<sup>total</sup> are equipped with a DOI and for 77.6% of the matched items, a DOI is available in MA (see Table 3). In the natural sciences, engineering and technology, medical and health sciences, and agricultural sciences, the proportion of matched items equipped with a DOI in MA is high (76.7% to 91.4%). This proportion is considerably lower in the social sciences (60.5%) and the humanities (37.5%). 12.6% of the matched items that have a DOI in ZORA<sup>total</sup> do not have one in MA. All DOIs of the matched items are valid in MA (i.e. they start with the prefix '10').

Table 3 Availability of DOIs in ZORA<sup>total</sup> and MA by research field

	ZORA <sup>total</sup>		MA	
	<i>n</i>	% DOI	<i>n</i>	% DOI
Total	91'215	51.6	48'231	77.6
Natural Sciences	15'270	72.9	11'274	76.7
Engineering & Technology	1'071	96.4	1'008	91.4
Medical & Health Sciences	32'893	75.5	25'349	81.0
Agricultural Sciences	5'237	63.1	3'175	81.3
Social Sciences	19'809	26.7	6'776	60.5
Humanities	15'854	7.9	1'468	37.5

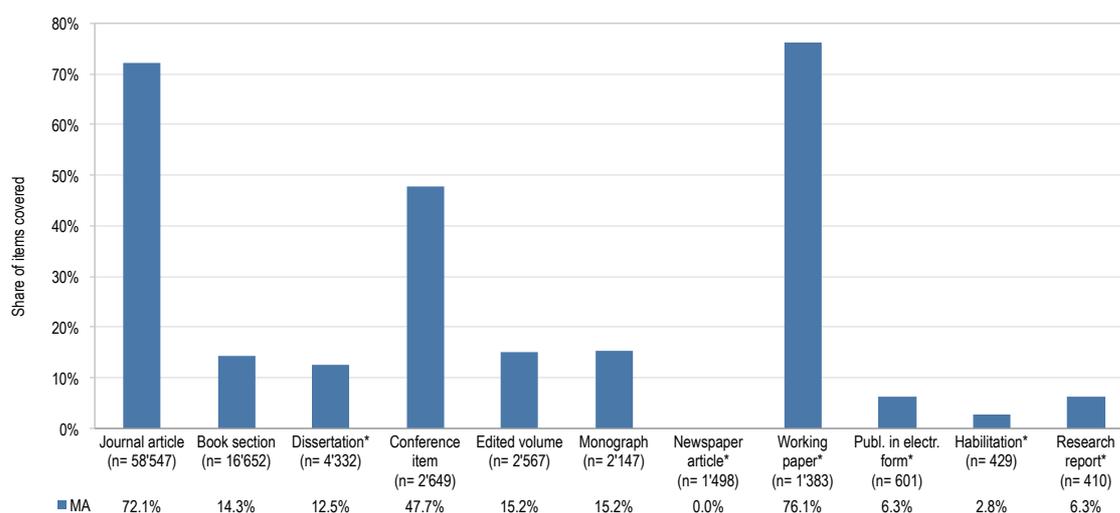
Other	5'209	49.4	3'543	71.8
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Note: A publication can be assigned to multiple fields. % DOI = share of items equipped with a DOI. Other = publications not assigned to a field since they belong to special collections.

## Coverage

MA contains 48'231 items from ZORA<sup>total</sup> (i.e. 52.9% of all items in the repository; see Table 1). MA covers working papers (76.1%), journal articles (72.1%) and conference items (47.7%) to a substantial extent (see Fig. 1). All other document types have a very low representation in MA (ranging from 2.8% for habilitations to 15.2% for edited volumes). None of the 1'498 newspaper articles can be found in MA. In the following, MA will be compared with Scopus and WoS on the basis of ZORA<sup>2008-2015</sup>.

**Fig. 1** Coverage of ZORA<sup>total</sup> by document type



Note: \* = document types specific to ZORA and/or belonging to grey literature.

### Overall and unique coverage

MA covers 56.6% of the items from ZORA<sup>2008-2015</sup>, Scopus covers 57.9%, and WoS 52.6%. There are 2'781 items from ZORA<sup>2008-2015</sup> that are exclusively covered by MA (i.e. 4.4% of all items), 1'655 by Scopus (2.6%), and 508 by WoS (0.8%; see Table 4). Scopus thus overall covers the most items from ZORA<sup>2008-2015</sup>, while MA covers the most items from ZORA<sup>2008-2015</sup> exclusively. WoS has the least overall as well as the least unique coverage.

Table 4 Overall and unique coverage of ZORA<sup>2008-2015</sup>

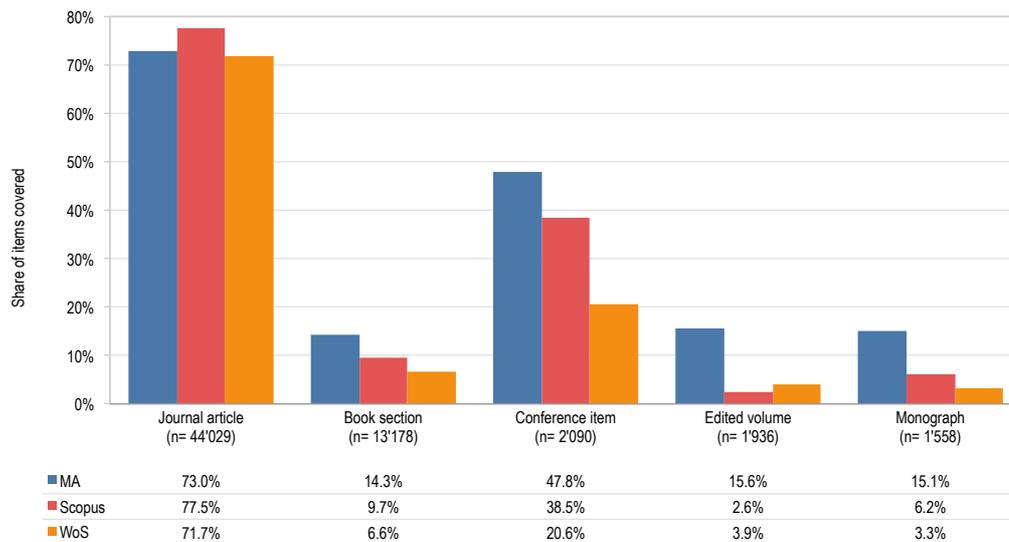
	MA		Scopus		WoS	
	No.	%	No.	%	No.	%
Overall coverage	35'557	56.6	36'351	57.9	33'000	52.6
Unique coverage	2'781	4.4	1'655	2.6	508	0.8

Note: % = share of items covered by database ( $N = 62'791$ ). Unique coverage = items covered exclusively by database.

### Document type

Of the three databases, Scopus has the best coverage of journal articles, which is the most frequent document type in the repository and accounts for more than two-thirds of the publications in ZORA<sup>2008-2015</sup>. In particular, Scopus covers 77.5% of the journal articles, MA 73%, and WoS 71.7% (see Fig. 2). However, MA surpasses Scopus and WoS clearly with respect to book-related document types (i.e. monographs, edited volumes, book sections). For example, MA covers 1.5 times more book sections and 2.5 times more monographs than Scopus. Moreover, MA covers 2.2 times more book sections and 4.6 times more monographs than WoS. In spite of that, the coverage of book-related items is still very low in MA and reaches max. 15.6% (edited volumes). In contrast, conference items are well covered in MA (47.8%) while the coverage of this document type is somewhat lower in Scopus (38.5%) and considerably lower in WoS (20.6%).

Fig. 2 Coverage of ZORA<sup>2008-2015</sup> by document type



### *Publication language and access status*

All three databases feature a high coverage of publications in English (78.2% to 83.2%) and a low coverage of non-English publications (5.1% to 11.2%; see Table 5). This is due to a high coverage of journal articles and conference items (see Fig. 2), which are mainly written in English, and a low coverage of book-related items, which are mainly published in languages other than English. With regard to the access status of full texts, all three databases have a high coverage of items that are not publicly accessible (75.2% to 80.3%) and, comparatively, a lower coverage of open access publications (59.8% to 66.1%; see Table 5). Items without full texts are covered the least (32.8% to 38.1%), as many of these items are book-related, which have a low coverage (see Fig. 2).

Table 5 Coverage of ZORA<sup>2008-2015</sup> by publication language and access status

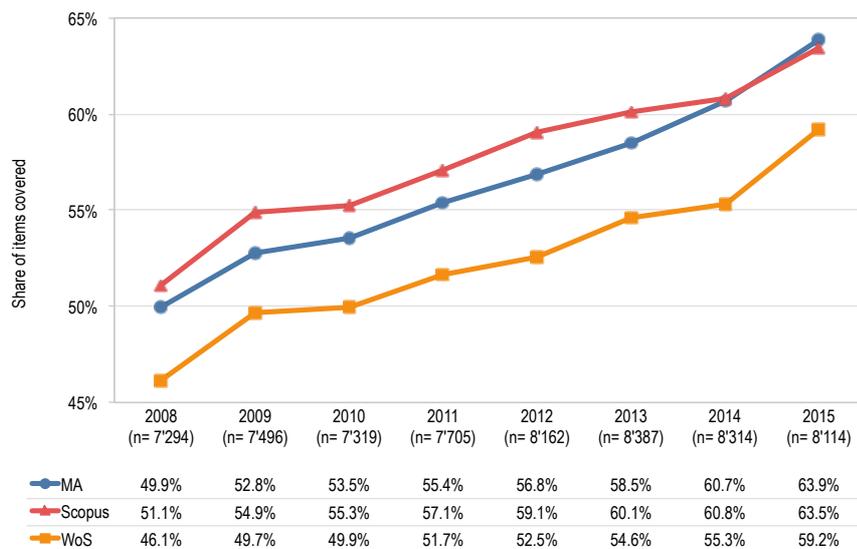
	ZORA <sup>2008-2015</sup>	MA	Scopus	WoS
	<i>n</i>	%	%	%
<b>Publication language</b>				
English	38'551	82.8	83.2	78.2
Non-English	20'855	8.2	11.2	5.1
Missing	3'385	56.4	57.2	52.4
<b>Access status of text</b>				
Public	20'139	65.1	66.1	59.8
Not public	16'434	75.8	80.3	75.2
No text deposited	26'218	38.1	37.6	32.8

*Note:* Not public = full text only available to members of the UZH due to copyright or embargo restrictions. No text deposited = items in ZORA for which no full text has been deposited.

### *Publication year*

From 2008 to 2015, the coverage of MA increased from 49.9% to 63.9%, the coverage of Scopus from 51.1% to 63.5%, and the coverage of WoS from 46.1% to 59.2%. All three databases show the same linear increase in coverage over time (see Fig. 3). Hence, there seems to be no data gap in MA with respect to the publication years 2008 to 2015. The growth pattern in Fig. 3 could mistakenly be interpreted as evidence for a substantial expansion of the coverage of the three databases. Instead, researchers at the UZH published more journal articles in 2015 (67.3% of all items in that year) than in 2008 (57.9% of all items in that year), which have a higher degree of coverage than other document types (see Fig. 2).

**Fig. 3** Coverage of ZORA<sup>2008-2015</sup> by publication year



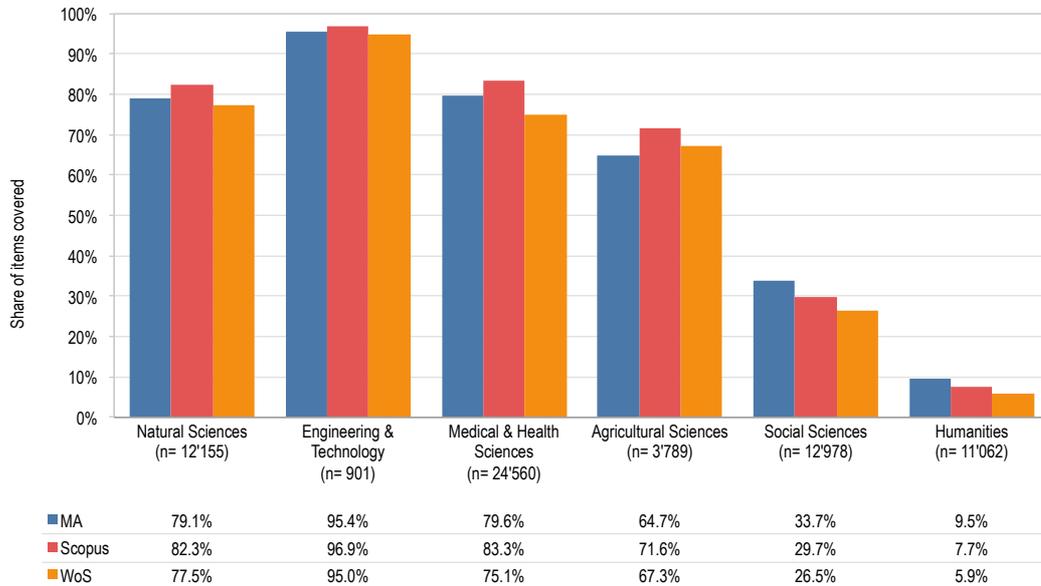
### *Research field*

Each item in ZORA is assigned to one or several institutes or clinics. This information, in combination with the revised field of science and technology (FOS) classification in the Frascati manual (OECD, 2007), is used to classify publications into fields, as the field attribute stored in MA is not suitable for this purpose (Hug et al., 2017). In particular, each of the 139 institutes and clinics at the UZH are assigned to one of the six major FOS fields and then each publication based on this assignment is linked to the FOS fields. If a publication is assigned to two or more fields, the publication will be counted and analyzed in each field. Hence, same as in the Frascati manual, there are no multi- or inter-disciplinary fields. For the social sciences and humanities (SSH) and the natural sciences, FOS subfields are also analyzed, since publication coverage is an issue in the SSH (Gumpenberger, Sorz, Wieland, & Gorraiz, 2016; Mongeon & Paul-Hus, 2016) as well as in mathematics and computer/information sciences (Bosman, van Mourik, Rasch, Sieverts, & Verhoeff, 2006; Larsen & von Ins, 2010).

A publication may be assigned to one or several FOS fields. For the 62'791 publications in ZORA<sup>2008-2015</sup>, 65'445 assignments were made, that is, on average one publication is assigned to 1.04 FOS fields. Of the three databases, Scopus has the best coverage of the natural sciences (82.3%), engineering and technology (96.9%), medical and health sciences (83.3%), and agricultural sciences (71.6%). In contrast, MA is the database that has the highest degree of coverage in the social sciences (33.7%) and humanities (9.5%). Overall, there are only small differences between the three databases regarding the coverage of FOS fields (see Fig.

4). However, with respect to MA, there are two exceptions. First, the differences between MA and Scopus are somewhat larger in the agricultural sciences (64.7% vs. 71.6%). Second, the differences between MA and WoS are somewhat larger in the social sciences (33.7% vs. 26.5%).

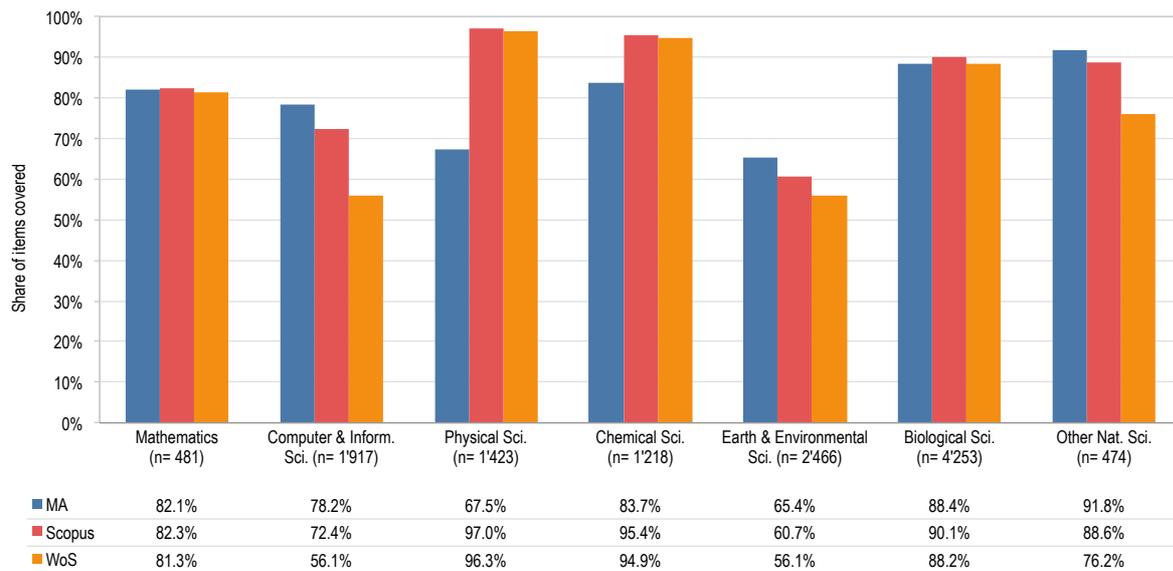
**Fig. 4** Coverage of ZORA<sup>2008-2015</sup> by FOS field



*Note:* A publication can be assigned to multiple fields.

While Scopus has the best coverage in 4 of the 7 FOS subfields of the natural sciences, MA has the best coverage in 3 subfields (see Fig. 5). The differences between the three databases are small in mathematics (81.3% to 82.3%) and biological sciences (88.2% to 90.1%). The differences are somewhat larger in the earth and environmental sciences (where MA covers 65.4% of the items, Scopus 60.7%, and WoS 56.1%) as well as in the chemical sciences (where Scopus covers 95.4% of the items, WoS 94.9%, and MA 83.7%). MA and Scopus cover considerably more items than WoS in the computer and information sciences (78.2% and 72.4% vs. 56.1%) as well as in other natural sciences (91.8% and 88.6% vs. 76.2%). Scopus and WoS, on the other hand, cover considerable more publications than MA in the physical sciences (97% and 96.3% vs. 67.5%). In comparison to WoS, the superior coverage of both MA and Scopus in the computer and information sciences is due to an extensive coverage of conference items (see Fig. 2), a document type particularly important in this field (Franceschet, 2010; Zhang, 2014). Mathematicians at the UZH suppose that the relatively high coverage of mathematics in all three databases could be due to above average numbers of articles published in quality journals.

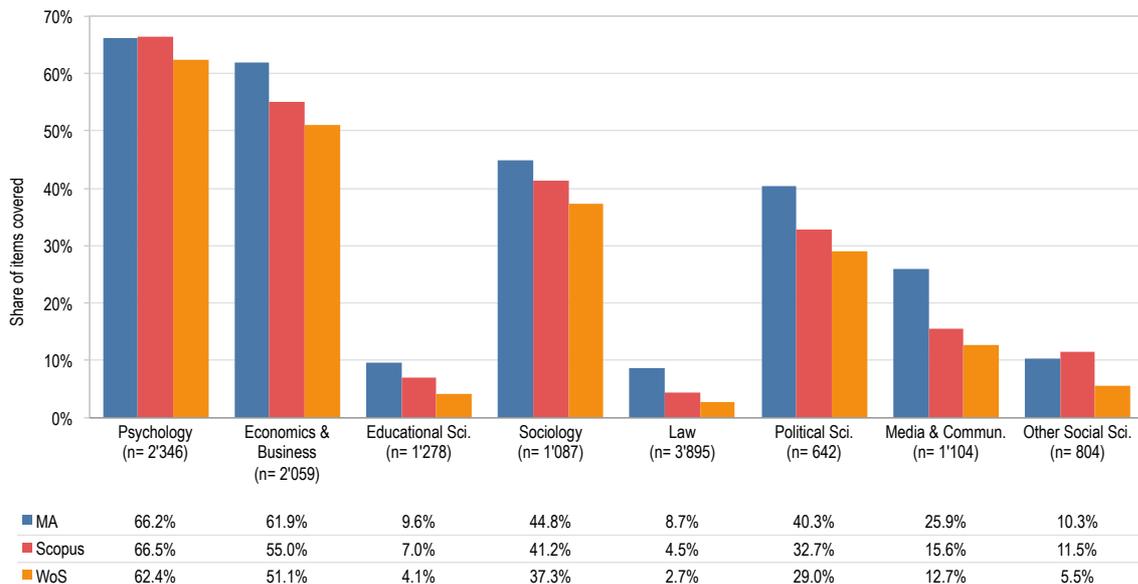
**Fig. 5** Coverage of ZORA<sup>2008-2015</sup> by FOS subfields of the Natural Sciences



*Note:* A publication can be assigned to multiple fields.

While MA has the best coverage in 6 of the 8 FOS subfields of the social sciences, Scopus has the best coverage in 2 subfields (see Fig. 6). The differences between the three databases are relatively small in psychology (62.2% to 66.5%) as well as in educational sciences (4.1% to 9.6%) and somewhat larger in sociology (37.3% to 44.8%), in law (2.7% to 8.7%), and in other social sciences (5.5% to 11.5%). MA particularly outperforms WoS in economics and business (61.9% vs. 51.1%), in political sciences (40.3% vs. 29.0%), and in media and communications (25.9% vs. 12.7%). In comparison to Scopus, the coverage of MA is only substantially higher in media and communications (25.9% vs. 15.6%).

**Fig. 6** Coverage of ZORA<sup>2008-2015</sup> by FOS subfields of the Social Sciences



*Note:* A publication can be assigned to multiple fields.

The differences between the three databases are small in four FOS subfields of the humanities (see Table 6). While MA covers the most items in languages and literatures (12.6%) as well as in philosophy, ethics, and religion (9.6%), Scopus leads in history and archeology (7.5%) as well as in art (3.6%). As a consequence, none of the subfields are well covered. This is due to the publication culture of the humanities, which is characterized by book-related items in non-English languages (e.g. Ochsner, Hug, & Daniel, 2016). Both book-related items and non-English items, which largely overlap, are hardly covered by the three databases (see Fig. 2 and Table 5).

Table 6 Coverage of ZORA<sup>2008-2015</sup> by FOS subfields of the Humanities

	ZORA <sup>2008-2015</sup>	MA	Scopus	WoS
	<i>n</i>	%	%	%
History & Archeology	2'078	6.7	7.5	5.2
Languages & Literatures	4'731	12.6	8.9	7.0
Philosophy, Ethics & Religion	2'922	9.6	7.9	6.1
Art	1'352	2.9	3.6	2.3

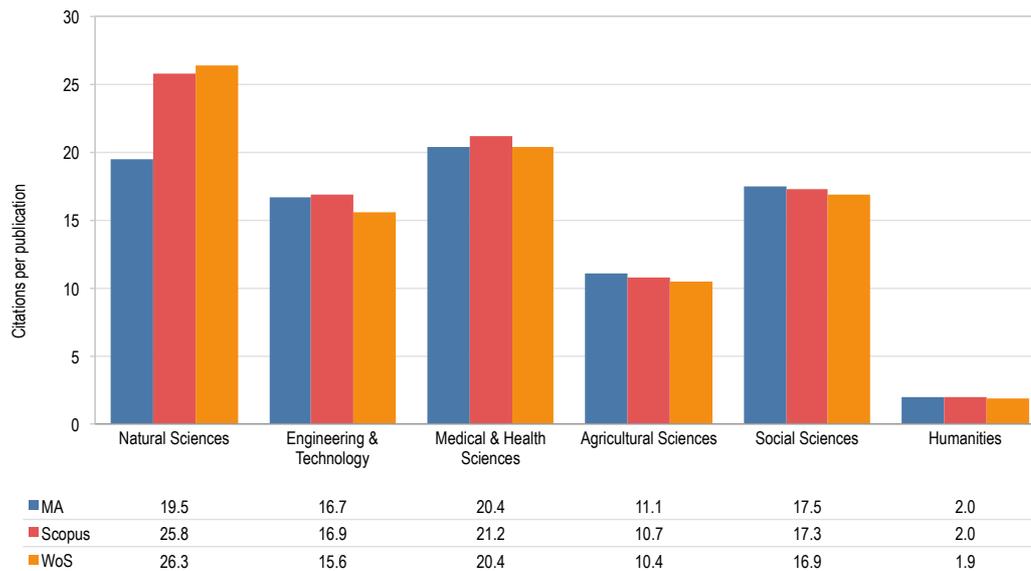
*Note:* A publication can be assigned to multiple fields.

## Citation counts

### *Citations per publication, uncitedness*

Overall, the items from ZORA<sup>2008-2015</sup> collect 745'758 citations in Scopus, 669'084 citations in WoS, and 652'081 citations in MA. Citations per publication (CPP) are almost identical in Scopus (20.5 CPP) and WoS (20.3 CPP). In contrast, MA (18.3 CPP) has 10.6% and 9.5% less CPP than Scopus and WoS respectively. This difference is due to the natural sciences, where CPP values in MA (19.5 CPP) are about a quarter lower than in Scopus (25.8 CPP) and WoS (26.3 CPP). Within the natural sciences, CPP values of MA, Scopus, and WoS are similar in four subfields but differ considerably in physical sciences (14.4 vs. 41.5 and 43.0 CPP), chemical sciences (14.8 vs. 20.6 and 20.1 CPP), and computer and information sciences (11.2 vs. 23.2 and 29.4 CPP). Apart from the natural sciences, CPP values in FOS fields are almost identical in all three databases (see Fig. 7). The humanities are the only FOS field with very low CPP values (approx. 2 CPP in each database). The share of uncited items from ZORA<sup>2008-2015</sup> in WoS (12.2%; 4'016 of 33'000 items) is slightly lower than in MA (16.1%; 5'720 of 35'557 items) and Scopus (15.2%; 5'536 of 36'351 items).

**Fig. 7** Citations per publication of ZORA<sup>2008-2015</sup> items by FOS field



### Rank correlation

Citation counts of publications collected in the three databases were correlated using Spearman's Rho (mean rank for ties) and Kendall's Tau-b. Overall, the citation counts of items from ZORA<sup>2008-2015</sup> have a very high correlation between Scopus and WoS ( $r_s = .96$ ,  $r_\tau = .89$ ;  $p < 0.01$ ). The correlations between MA and Scopus ( $r_s = .90$ ,  $r_\tau = .80$ ;  $p < 0.01$ ) as well as between MA and WoS ( $r_s = .89$ ,  $r_\tau = .79$ ;  $p < 0.01$ ) are slightly lower. These correlation patterns hold true for all FOS fields (see Table 7). The humanities are the only field with somewhat weaker correlations (MA / Scopus:  $r_s = .73$ ,  $r_\tau = .65$ ; MA / WoS:  $r_s = .74$ ,  $r_\tau = .64$ ; Scopus / WoS:  $r_s = .89$ ,  $r_\tau = .88$ ).

**Table 7** Rank correlations of ZORA<sup>2008-2015</sup> items by FOS fields based on citation counts

	MA / Scopus		MA / WoS		Scopus / WoS	
	<i>n</i>	$r_s / r_\tau$	<i>n</i>	$r_s / r_\tau$	<i>n</i>	$r_s / r_\tau$
All fields	32'164	.90	29'960	.89	31'880	.96
		.80		.79		.89
Natural Sciences	8'849	.86	8'356	.85	9'148	.96
		.74		.72		.89
Engineering & Technology	842	.93	825	.93	848	.97
		.83		.82		.91
Medical & Health Sciences	18'678	.93	17'377	.93	18'194	.97
		.84		.84		.90
Agricultural Sciences	2'310	.93	2'246	.93	2'503	.96

		.83		.83		.90
Social Sciences	3'357	.83	3'073	.85	3'167	.96
		.73		.74		.89
Humanities	400	.73	308	.74	347	.89
		.65		.64		.88

*Note:*  $n$  = number of items covered in two databases at the same time.  $r_s$  = Spearman's Rho (mean rank for ties).  $r_\tau$  = Kendall's Tau-b. All correlations  $p < 0.01$ .

## Discussion

As the DOI of a publication cannot be used to retrieve metadata from MA, we exploited the title of publications. In particular, we wrote a Perl script that retrieves publications either based on the exact title (ti\_ex mode) or based on the title words (ti\_wo mode) via the AK API. While the ti\_ex mode and the ti\_wo mode performed equal in terms of recall, ti\_ex had a higher precision than ti\_wo. Since each mode has retrieved items that the other has not, we suggest employing both modes to maximize the number of retrieved items. In our study, almost all retrieved items that match publications from ZORA rank in the top three in the result set of the AK API (ti\_ex: 99.4% of the matched publications; ti\_wo: 98.4%). These results indicate that both modes translate title information into meaningful MA requests – and that MA delivers very precise results. However, permitting DOI in query expressions of the AK API would greatly facilitate the retrieval of metadata (Hug et al., 2017). According to the developer team of MA, Microsoft considers implementing DOI queries in the future (A. Chen, personal communication, March 31, 2017).

We found that 89.5% of the items retrieved from MA have correct publication years, 7.0% differ by  $\pm 1$  year, and 3.5% feature larger differences. These results corroborate the findings of Herrmannova and Knoth (2016a), who report almost identical numbers (i.e. 88%, 8%, and 4%). With respect to authorship, our analysis shows that 95.1% of the retrieved journal articles list the correct number of authors, 1.7% differ by  $\pm 1$  author, and 3.2% exhibit larger differences. According to our analysis, a maximum of 50 authors per publication could be retrieved with the AK API. This would partly explain why there are occasionally fewer authors in MA. The availability of DOIs for different research fields in MA is comparable to those in Scopus and WoS reported by Gorraiz, Melero-Fuentes, Gumpenberger, & Valderrama-Zurian (2016). However, 12.6% of the publications that have a DOI in ZORA do not have one in MA.

MA covers 52.9% of all publications in the repository (i.e. ZORA<sup>total</sup>). Journal articles, working papers, and conference items are covered to a substantial extent. All other document types have a very low representation in MA (ranging from 2.8% for habilitations to 15.2% for edited volumes). None of the newspaper articles from ZORA<sup>total</sup> could be found in MA, which indicates that MA manages to separate scholarly from non-scholarly content. Performing this discrimination successfully proves to be difficult for academic search engines such as GS (Orduna-Malea, Ayllón, Martín-Martín, & López-Cózar, 2015). The comparison of the coverage of MA with Scopus and WoS, which was constrained to document types included in Scopus and WoS, reveals that Scopus covers overall the most items from ZORA<sup>2008-2015</sup>, while MA covers the most items from ZORA<sup>2008-2015</sup> exclusively. WoS has the least overall as well as the least unique coverage. However, the differences between MA and the two benchmark databases are rather small with respect to overall and unique coverage. A more detailed analysis unveils further similarities and some differences. While Scopus has a slightly better coverage of journal articles than MA and WoS, MA surpasses Scopus and WoS clearly with respect to book-related document types (i.e. monographs, edited volumes, book sections) and conference items. With regard to FOS fields, there are only small differences between the databases. In particular, all databases show significant weaknesses in covering the SSH. Thus, MA suffers from the same bias with regard to the SSH as Scopus and WoS (Gumpenberger et al., 2016; Mongeon & Paul-Hus, 2016). Within the natural sciences, the coverage of MA is noticeably lower than Scopus and WoS in the physical and chemical sciences but higher in computer/information sciences. Bar-Ilan (2008) and Bornmann et al. (2009) report similar findings from comparisons of GS, WoS and Scopus. Hence, the observed pattern within the natural sciences seems not to be uncommon among academic search engines. With regard to publication language and access status of full texts, the three databases perform similarly in our analysis. They feature a high coverage of publications in English and a low coverage of non-English publications. Items not publicly accessible are covered to a high degree and open access publications to a somewhat lower degree. Hence, MA exhibits the same language and open access bias as Scopus and WoS (Mas-Bleda & Thelwall, 2016; Moed, Bar-Ilan, & Halevi, 2016). We found that citations per publication (CPP) are almost identical in Scopus and WoS. In contrast, MA has overall about 10% less CPP due to lower values in physical, chemical and computer/information sciences. In the other FOS fields, the three databases have equal CPP. With regard to correlations of citation counts, we observed the following pattern across FOS fields: While the rank correlations between Scopus and WoS are *very* high, the correlations between MA and the benchmark

databases are high. Overall, our findings indicate that MA performs similarly to Scopus and WoS with respect to coverage and citations of journal articles, conference items, monographs, edited volumes, and book sections. On the one hand, this speaks for the quality of MA, and on the other hand, this is somewhat ‘deflating’ as one expects a more comprehensive coverage of a database that gets the majority of its data from indexed web pages (Sinha et al., 2015). However, such expectations are perhaps misplaced since MA is only in its third year and still developing. Moreover, academic search engines do not necessarily outperform Scopus and WoS as Waltman (2016, p. 396) concludes “that the coverage of Google Scholar is not consistently broader than the coverage of WoS and Scopus.”

Many academic search engines are rather opaque regarding their overall coverage and the sources they cover (Ortega, 2014). According to Moed et al. (2016), this is particularly true for GS, probably the closest competitor of MA. Despite the open approach taken by the developer team of MA, the only known sources of MA are ‘metadata feeds from publishers’ and ‘web pages indexed by Bing’ (Sinha et al., 2015). Hence, future research needs to address the source coverage of MA. Moreover, it would be helpful if Microsoft were to elaborate on its coverage policy.

## **Conclusion**

Although there are not many studies on MA yet, we dare to conclude that MA is on the verge of becoming a bibliometric superpower. We base this conclusion on the fast and ongoing development of MA, on the performance of MA in terms of coverage and citations (see present study and Harzing & Alakangas, 2017), on the functionality of the AK API as well as on the structure and richness of MAG data (see Hug et al., 2017). The features of MA are not only advantageous for bibliometric purposes but also for library applications, such as enriching institutional repositories or assessing library collection and acquisitions by using reference information. The present study only examined publications from 2008 to 2015. Hence, further studies are needed to assess the coverage of older publications in MA. Furthermore, our findings and conclusion depend on how open, transparent, and accessible MA data will remain in the future as well as on the metadata quality of MA, which has not yet been investigated in detail. Therefore, future studies need to evaluate the data quality of MA.

## Acknowledgments

The authors thank the ZORA editorial team for their advice, Robin Haunschild for comments, and Mirjam Aeschbach for proofreading.

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