How Do Researchers Manage their Data? An Empirical Comparison between Policies and Practice

Anne Thoring[1], Dominik Rudolph[1], Raimund Vogl[1]

[1]Westfälische Wilhelms-Universität Münster, ZIV, Röntgenstraße 7-13, 48149 Münster/Germany, {a.thoring|d.rudolph|rvogl}@uni-muenster.de

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1. ABSTRACT

Several academic organizations like the German Research Foundation (DFG) increasingly emphasize the importance of a professional research data management for the scientific community. Regulations for secure storage and making data available in terms of open science need to be established, to fully harness the immense value of research data as a proof of accuracy and as a basis for future studies. With 667 completed questionnaires by researchers at Münster University (WWU), this survey aims to provide insights on the implementation of research data management in research practice generally and in different academic disciplines in particular.

2. INTRODUCTION

During the research process, large amounts of valuable data are generated. Preserving it digitally and making it available to other scientists are the two most important challenges to tackle in order to capitalize on the advantages of e-science (Bell, 2009; Büttner, Hobohm, & Müller, 2011; Lynch, 2009). Although in this context, a professional research data management, characterized by adequate infrastructure, regulations and human resources, is indispensable (Bell, Hey, & Szalay, 2009, pp. 1297–1298), it is something of rarity in the scientific practice (Rümpel & Büttner, 2010; Strathmann, 2012; Winkler-Nees & Stefan, 2012). In research literature, an analogical lack of empirical data on the handling of research data in practice exists – forming the starting point for this survey in 2014. A quantitative approach was used to question approximately 1,000 scientists of Münster University (WWU) about the status quo of research data management, in order to form a solid basis for improvement.

When discussing the accessibility of research data, it is inevitable to come across the concept of "open science" (Fry, Schroeder, & den Besten, 2009). According to Wagner, the accessibility of primary data is nothing less than "science's court of appeal" (Wagner, 2000, p. 47) as it allows other scientists to carry out independent re-analyses which can either verify and thereby strengthen the results, or uncover errors or even manipulations. However, accessibility per se might not be enough as Marris points out: „What do you do if you are suspicious about a paper, you ask to see the data and you get 25 cardboard boxes, 4 CDs and would have to hire a biostatistician for three months" (Marris, 2006, pp. 520–521)?

Clearly, to be valuable to other researchers, the data needs to be preprocessed, but on the other hand, it is also necessary to consider how much additional effort is acceptable to do so. In the science system, verification processes usually take place in the context of review procedures for the publication in scientific journals (Mittler, 2007). Data accessibility is limited to those individuals involved. With a broader accessibility of research data, numerous concerns arise, e.g. when it comes to particularly sensitive patient records (Pfeiffenberger, 2007, pp. 207–210) or to the point that data without context or interpretation may be misleading or useless (Rosenblum, 2009, pp. 19–22). Furthermore, researchers raise major concerns over uncontrolled reuse and possible abuse of their data (Winkler-Nees & Stefan, 2012). The high autonomy of researchers in Germany and the associated

actual or merely perceived rights of ownership over the acquired data are identified as further obstacles to a disclosure of research data (Winkler-Nees & Stefan, 2012).

Against this background, our first research question is: “What relevance does the idea of open access have for making research data available in scientific practice?” To answer this question, the following criteria (Open Science Criteria, OC) are examined:

- OC1 Making available of research data
- OC2 Regulation of disclosure by binding guidelines

Aside from access, archiving is another essential aspect of research data management. The German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), for example, advises every research institution to set up clear rules not only for the accessibility of research data but also for storage (Deutsche Forschungsgemeinschaft, 2013). According to its ‘guidelines for ensuring good scientific practice’, “[p]rimary data as the basis for publications shall be kept for ten years on durable and secured storage media at the institution where they were generated” (Deutsche Forschungsgemeinschaft, 2013). Against this background and bearing in mind the general worth of data in today’s society, it is astonishing that, according to estimates, up to 90 percent of research data are irretrievably lost shortly after finishing a research project (Winkler-Nees, 2011). Then again, the reasons for such a low degree of implementation are fundamental: the trustworthiness and persistence of the storage locations, the lack of adequate licensing models to protect data proprietary rights and the lack of necessary know-how (Bertelmann & Hübner, 2007, pp. 246–250). Professional research data management requires domain-specific, methodological and technical expertise as well as knowledge of legal aspects and librarianship. Therefore, not only scientists need to be involved in such a complex task, but “[…] information and computer scientists, database and software engineers and programmers, disciplinary experts, curators and expert annotators, librarians, archivists, and others, who are crucial to the successful management of a digital data collection“ (National Science Board, 2005).

Our second research question focuses on the level of professionalism in the archiving of data: “How far have researchers progressed in terms of professional archiving?“ To answer this question the following criteria (Archiving Criteria, AC) are examined:

- AC1 Non-local storage on network drives or subject-specific repositories provided by professional IT facilities within the university
- AC2 Long-term storage on durable media for at least 10 years
- AC3 Regular backups
- AC4 Binding regulation by directives for the safe storage and systematic recording in reference databases
- AC5 Involvement of professional data specialists from the fields of IT and librarianship in the archiving process
- AC6 Targeted archiving with a clear purpose of use

Our third research question focuses on the scientists’ know-how about research data management, aiming to identify subject areas with particular need for advice: “How do researchers assess their knowledge of dealing with research data?” To answer this question, the following (Knowledge Criteria, KC) are examined:

- KC1 Knowledge of research data management
- KC2 Need for advice

To date, there are only few empirical studies on the subject of research data management in scientific practice (Campbell et al., 2002; Savage & Vickers, 2009; Simukovic, Kindling, & Schirmbacher, 2013) which are characterized by limitations (i.e. very small samples, restrictions to individual departments) and show heterogeneous results. The present study thus largely enters new territory and is designed explorative.

3. RESEARCH METHOD

The items of the online questionnaire were phrased predominantly on the basis of surveys conducted before (Quandt, 2012). Modifications were made with regard to the research questions and the specific situation of the University of Münster. The study was conducted as an online survey among the scientific staff of Münster University from July 21st to August 8th, 2014. The following analysis is based on the 667 duly completed questionnaires which remained after data cleansing. According to the current state of knowledge, this is one of the largest samples on research data management. About one-fifth of the respondents (19%) are professors, 79 percent are members of the non-professorial academic staff (mainly research assistants, academic counselors, PhD students). This approximately corresponds to the distribution at the University of Münster (professorships account for 23 % of the scientific staff).

4. RESULTS

4.1. Open Science

With respect to the first criterion of open science – making available (OC1) – results show only a low degree of realization in practice (Table 1). Currently, the vast majority of researchers does not grant other scientists access to research data at all or only on explicit request. Only about one quarter makes data available – usually in the context of a publication by a publishing house. Similar results were provided by a study at HU Berlin (Simukovic et al., 2013). Apparently to date, the open science idea is most present in mathematics, while it is practiced very rarely in economics and law.

Table 1: Making Research Data Available to Other Researchers (Results in percent, N=667)

	C1	C2	C3	C4	C5	Ø
Making data available	25.4	27.9	38.8	30.8	16.1	27.0
Thereof: via a subject-specific repository	4.1	5.7	24.5	4.1	0.0	4.2
Thereof: in the context of a publication by a publishing house	11.4	19.7	12.2	23.1	8.1	17.4
Existence of Guidelines	16.6	33.6	20.4	26.1	12.9	21.9
Constraints						
Legal reasons	53.5	62.5	50.0	42.5	67.3	49.7
Data unsuitable	41.0	47.7	46.7	51.6	44.2	48.5
Lack of time	19.4	17.0	20.0	15.9	25.0	17.2
Lack of an appropriate platform	18.8	34.1	30.0	25.0	34.6	24.2

C1: Humanities and social sciences C2: Life sciences C3: Mathematics C4: Natural sciences C5: Economics and law.

With respect to the second criterion – existence of guidelines which regulate the disclosure (OC2) as demanded by the DFG (Deutsche Forschungsgemeinschaft, 2013) – results, likewise, show only a low degree of fulfillment. Most likely such guidelines seem to exist in the life and natural sciences, but here, as well, more than two-thirds state that they do not know any corresponding regulations.

When asked about the reasons against making research data available, respondents primarily mention legal restrictions (50%). Also, the unsuitability of data, in the sense that they are misleading or useless without context and interpretation, is a reason stated by every second interviewee. The lack of a suitable platform where data could be made available with little effort seems to be another obstacle (24%). Moreover, researchers often do not have enough time for making their research data available because of their other duties (17%). In this context, the fact that data have to be processed before disclosure is another reason. In addition, some researchers are afraid that others could publish their findings first and adorn themselves with borrowed plumes. Last, the fear of unwanted players (keyword NSA) accessing the data is relevant, too.

4.2. Archiving of Research Data

In its Guidelines for Ensuring Good Scientific Practice, the DFG prescribes storage "on durable and secured storage media at the institution where they were generated" (Deutsche Forschungsgemeinschaft, 2013, p. 21, translation by the authors). With respect to the AC1 criterion, very heterogeneous results are revealed (Table 2).

Table 2: Storage Locations (Results in percent, N=667)

	C1	C2	C3	C4	C5	Ø
Internal storage locations						
Office computer	59.6	76.2	75.5	71.2	71.0	69.9
Server of the department	32.1	61.5	57.1	56.0	40.3	48.3
Server of the computing center	36.8	36.1	42.9	34.9	30.6	34.5
External storage providers						
Subject-specific repository	7.3	13.1	18.4	7.7	8.1	7.5
External cloud provider	17.1	12.3	26.5	15.7	32.3	17.5
Other locations						
Private computer	43.0	28.7	38.8	34.6	24.2	35.7
External data storage media	61.1	72.1	46.9	67.3	41.9	62.8

C1: Humanities and social sciences C2: Life sciences C3: Mathematics C4: Natural sciences C5: Economics and law

The large number of multiple answers reflects that the data is typically stored in multiple locations – 2.8 on average. In addition to local storage on office computers (70%), where the data usually is evaluated and processed for publication too, storing data on external storage media (e.g. burned CDs / DVDs, external hard disks) is still very popular (63%). The latter, however, are very inflexible and suitable only for small data volumes, making the disclosure of data to external third parties almost impossible and entailing additional disadvantages with regard to the archiving duration. The great importance of storing data on private devices (36%) or servers of external cloud providers (18%) – that is locations which are not part of the universities' IT structures and have a significantly increased risk of data loss, copyright loss or even data theft – is to be treated as particularly critical. Especially external cloud storages are not a suitable location for important or even sensitive research data, because the servers of commercial providers are mostly abroad. As to the long-term perspective local storage is critical as well, because standard PCs are sorted out usually after five to seven years.

However, a large part of researchers also uses services provided by their computing center (35%) or their departments' decentralized IT facilities (48%) for data storage. In comparison, subject-specific repositories like arxiv.org in the mathematics are surprisingly of minor relevance (8%). Again, the study identifies significant differences between the disciplines: especially in the humanities and social sciences as well as mathematics storage on private devices is common. External cloud providers, on the other hand, are used mainly in the fields of economics and law as well as mathematics.

According to the DFG Guidelines for Ensuring Good Scientific Practice (p. 21) a secure storage for at least 10 years has to be ensured (AC2). Exceptions are allowed only if the data "cannot be stored on durable and secured storage media" (p. 22, translation by the authors). Considering that the guidelines became effective in 2010, only 4 years prior to this survey, a storage duration of at least 5 years is seen as a strong indication for compliance here. On this basis the majority of researchers (53%) seems to comply with the DFG policy already, especially in the life sciences (75%) (Table 3). However, almost one-third does not know exactly how long the data of current research projects are kept, suggesting that there still is a great ignorance of the storage processes.

Table 3: Archiving Routines (Results in percent, N=667)

	C1	C2	C3	C4	C5	Ø
Storage duration: at least 5 years	47.7	75.4	38.8	54.7	40.3	52.5
Backup routine: regular, at least quarterly, backups	33.2	47.5	59.2	50.0	32.3	43.5

C1: Humanities and social sciences C2: Life sciences C3: Mathematics C4: Natural sciences C5: Economics and law

The secure storage stipulated in the DFG guidelines implicitly assumes regular data backups (AC3). 85 percent of the researchers stated that they generally generate backups – often not on a regular basis, though, as required for a professional research data management, but only ad hoc or at random times. No more than 44 percent of researchers produce a regular, at least quarterly, backup. As to this question too, many of the respondents are unable to make a statement. A comparison of the disciplines shows that backups are least important in the humanities and social sciences as well as in economics and law, while sensitivity for the issue of data loss is particularly high in mathematics.

Table 4: Knowledge of Guidelines for Storage and Recording (Results in percent, N=667)

	C1	C2	C3	C4	C5	Ø
University directives						
Data backup for a certain duration	8.8	37.7	20.4	26.1	3.2	19.9
Systematic recording of research data in internal reference databases	4.7	5.7	4.1	6.9	3.2	5.8
Directives of external investors	20.2	31.1	24.5	18.7	16.1	19.8

C1: Humanities and social sciences C2: Life sciences C3: Mathematics C4: Natural sciences C5: Economics and law

With respect to the fourth criterion of a professional long-term archiving – existence of explicit guidelines and directives for the storage and recording of data in reference databases (AC4) – results show a rather low degree of compliance. Merely one out of five researchers knows guidelines for data storage (Table 4). Mainly, they are from the fields of life and natural sciences, as in other disciplines such regulations seem to exist only sporadically. Guidelines for the verification of data, on the other hand, are available and known only to a negligible extent in all disciplines. Just as internal university directives, requirements for the handling of research data issued by external investors are not universally relevant, yet. They primarily exist in the life sciences, where about one in three researchers has had corresponding experiences.

Table 5: Persons in Charge for Data Archiving (Results in percent, N=667)

	C1	C2	C3	C4	C5	Ø
Professors	56.5	57.4	53.1	49.7	59.7	52.6
Non-professorial academic staff	86.0	95.9	91.8	94.2	85.5	91.0
Student assistants	74.6	50.8	49.0	42.3	77.4	54.1
IT staff	7.8	59.8	18.4	39.6	6.5	29.2
Library staff	4.1	0.8	2.0	0.8	3.2	1.5
External service providers	12.4	9.0	6.1	4.4	8.1	6.9

C1: Humanities and social sciences C2: Life sciences C3: Mathematics C4: Natural sciences C5: Economics and law

Another important aspect of a professional long-term archiving is the involvement of data specialists (AC5). According to the survey results (Table 5), the non-professorial academic staff is usually responsible for data archiving. Doctoral students who account for a large part of the academic staff and naturally work on their research projects on their own, serve as the basic explanation for this. What is surprising is the great importance of student assistants that are mentioned even more often than professors. Especially in the fields of economics and law as well as humanities and social sciences research data management is very often assigned to student assistants.

IT personnel plays an important role as well, especially when specific infrastructure is needed due to high volumes of data. This is particularly true in the life sciences and, to a lesser extent, in the natural sciences, while technical staff is almost irrelevant in the humanities and social sciences. In all disciplines the services of external providers are sought only in exceptional cases. Likewise, library staff is involved rarely in the archiving process yet.

Table 6: Storage Purposes (Results in percent, N=667)

	C1	C2	C3	C4	C5	Ø
Proof of replicability	74.6	94.3	89.8	90.1	77.4	84.9
Researchers‘ own reanalyses	81.3	88.5	95.9	87.1	77.4	84.9
Others‘ reanalyses	42.0	48.4	57.1	48.1	24.2	42.4
Scientific education	40.4	23.0	42.9	22.8	32.3	27.3
Exclusion of legal risks	39.9	59.8	26.5	42.6	27.4	42.1
Preservation as historically relevant information	31.1	9.0	14.3	8.0	11.3	14.2
Without cause	13.5	9.8	26.5	15.4	19.4	15.3

C1: Humanities and social sciences C2: Life sciences C3: Mathematics C4: Natural sciences C5: Economics and law

The storage of research data can serve different purposes, e.g. as a basis for further research or as proof of the correct implementation of the study (Table 6). According to the respondents, these two reasons are most, and almost equally, important. Especially in the life sciences, the elimination of legal risks (e.g. regarding data protection) plays an important role as well. The relevance of another storage purpose, the re-analysis of data by other researchers, varies greatly depending on the discipline. Whereas about 57 percent of researchers in mathematics keep this reason in mind, it is only one in four in economics and law, and one in two in the other disciplines. In the humanities and social sciences as well as mathematics, research data is often used for teaching purposes, too. Moreover, the preservation of data as an important time-specific description for future generations plays a role in the humanities. In many cases, however, researchers indicate that there is no explicit reason for storage, but obviously data are just not deleted. Here it can be assumed that, in general, data are not stored in a processed state but as-is.

Table 7: Willingness to Use University Owned Data Archives (Results in percent, N=667)

	C1	C2	C3	C4	C5	Ø
Willingness to use university owned data archives (definitely/probably)	50.8	54.1	63.3	45.1	46.8	48.1

C1: Humanities and social sciences C2: Life sciences C3: Mathematics C4: Natural sciences C5: Economics and law

In summary the results show that apparently there are hardly any satisfactory tools for secure archiving and easy management of research data at the moment. Therefore, researchers often choose uncomfortable or unsafe storage locations and the time for data handling is perceived as too long. One possible solution would be that the university itself provides an appropriate data archive. Of course researchers need to be highly willing to use such a platform, in order to justify its establishment. In fact, at least 48 percent of respondents would most likely use a university owned archive, another 30 percent would do so under certain conditions (Table 7).

4.3. State of knowledge

The results above show that, to some extent, there are significant differences between the theoretical ideal of a professional research data management and the actual practice, particularly in the social sciences and humanities, but also in the other disciplines. One possible cause could be a lack of knowledge (KC1). This is confirmed by the survey (Table 8).

Table 8: State of Knowledge and Need for Advice (Results in percent, N=667)

	C1	C2	C3	C4	C5	Ø
Good to very good knowledge	14.5	29.5	44.9	21.2	17.7	20.0
Need for advice	87.6	87.7	79.6	82.1	79.0	83.7
General questions	36.3	40.2	34.7	41.5	33.9	38.7
Publishing and quotation	37.3	27.0	30.6	32.7	33.9	33.1
Technical questions	50.8	59.0	40.8	46.7	32.3	48.4
Legal questions	62.2	57.4	57.1	46.4	53.2	52.9
Data management plans	28.5	36.9	26.5	27.2	21.0	28.5
Third-party funded projects	35.8	36.1	22.4	27.2	24.2	29.8

C1: Humanities and social sciences C2: Life sciences C3: Mathematics C4: Natural sciences C5: Economics and law

No more than 20 percent claim to have good or very good knowledge on the subject of research data, and 42 percent think their knowledge is below average. Thus, there is still a considerable need for information and advice. Interestingly, even in the life sciences only one third of researchers feels well-informed – this being the discipline with the overall highest standard when dealing with research data. Accordingly, the vast majority calls for special counseling services (KC2). Particularly technical and legal questions are of interest. The state of knowledge on the subject of research data varies between the disciplines. While especially mathematicians claim to have a rather good knowledge, researchers from the humanities and social sciences as well as economics and jurists notice a great backlog demand in their respective disciplines.

5. DISCUSSION

With regard to the research questions, the rather pessimistic impression of Rümpel and Bütter (2010) and Winkler-Nees and Stefan (2012) have to be confirmed: In terms of making research data available, in terms of long-term archiving and in terms of researchers' knowledge, there still is a considerable need to catch up toward a professional research data management. Albeit a generally low

standard, researchers in the life and natural sciences are apparently prepared best for data-centric science. Nevertheless, in all disciplines there is a lack of clear guidelines and directives, trained personnel, knowledge, and simple technical tools which make the handling of research data manageable.

Pfeiffenberger suspects "that most universities will not be able to operate a qualitatively and quantitatively appropriate "Institutional Repository" for *all* data categories of their respective disciplines" (Pfeiffenberger, 2007, p. 12), because of a lack of discipline-specifically qualified staff. Instead, he suggests that the universities' computing centers and libraries should offer technical resources particularly for safe data storage as well as best practice handouts or training courses. This also corresponds to the results of this study where researchers communicated a great need for advisory services. According to Pfeiffenberger (2007), cooperative efforts of several institutions across university boundaries and the establishment of an appropriate technical infrastructure and corresponding expertise constitute the answer to the problem. This would argue for the use of existing storage infrastructures which are jointly operated by several universities, such as the cloud storage projects in Baden-Württemberg (Schlitter, Yasnogor, & Srajc, 2014) or North Rhine-Westphalia (Stieglitz, Meske, Vogl, Rudolph, & Öksüz, 2014). Since the conditions of the individual disciplines vary widely, subject-specific repository solutions are needed additionally (Bertelmann & Hübner, 2007). With regard to making research data available, a system that allows for flexible disclosure seems most suitable due to the existing legal restrictions and the high reluctance of researchers to fully disclose their data.

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7. AUTHORS' BIOGRAPHIES

Anne Thoring is a research assistant for public relations and marketing at the Zentrum für Informationsverarbeitung (the computing center) of the University of Münster (Germany). She graduated from University College London (UK) and the University of Münster with degrees in communication sciences, publishing and strategic communication. Her research focuses on strategies and tools of corporate communications.

Dominik Rudolph is a research assistant and executive secretary of the Zentrum für Informationsverarbeitung (the computing center) of the University of Münster (Germany). He received his Ph.D. from the University of Münster, where he also studied communication sciences, economics and modern history. His graduate thesis has been awarded as one of the best dissertations in 2014 (German Thesis Award). In his research he focusses on the diffusion of media innovations from the user perspective.

Raimund Vogl holds a Ph.D. in elementary particle physics from the University of Innsbruck (Austria). After completing his Ph.D. studies in 1995, he joined Innsbruck University Hospital as IT manager for medical image data solutions and moved on to be deputy head of IT. He served as a lecturer in medical informatics at UMIT (Hall, Austria) and as managing director for a medical image data management software company (icoserve, Innsbruck) and for a center of excellence in medical informatics (HITT, Innsbruck). Since 2007 he has been director of the Zentrum für Informationsverarbeitung (the university computing center) of the University of Münster (Germany). His research interests focus on management of complex information systems and information infrastructures.