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Research Data Management in the Croatian Academic Community: A Research Study

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Abstract: This paper presents the results of an empirical research study of Croatian scientists' use and management of research data. This research study was carried out from 28 June 2023 until 31 August 2023 using an online questionnaire consisting of 28 questions. The answers of 584 respondents working in science were filtered out for further analysis. About three-quarters of the respondents used the research data of other scientists successfully. Research data were mostly acquired from colleagues from the same department or institution. Roughly half of the respondents did not ask other scientists directly for their research data. Research data are important to the respondents mostly for raising the quality of research. Repeating someone else's research by using their research data is still a problem. Less than one-third of the respondents provided full access to their research data mostly due to their fear of misuse. The benefits of research data sharing were recognized but few of the respondents received any reward for it. Archiving research data is a significant problem for the respondents as they dominantly use their own computers prone to failure for that activity and do not think about long-term preservation. Finally, the respondents lacked deeper knowledge of research data management.

Keywords: research data; research data sharing; research data reuse; research data management; Croatia

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1. Introduction

The last three decades have been marked by some major developments and innovations in digital technologies, providing support to newly created paradigms of e-science and open science and to activities related to research data such as creating, collecting, storing, sharing and use of the data, making modern science increasingly digital and data-intensive [1]. Since the 1990s and the advent of e-science, research data have become a popular topic of many theoretical and practical scientific endeavors. During the same period, scientific and professional papers and books have been published describing the positive impact of research data on the development of modern science. Consequently, the value of research data has increased and, for many, they have become a new currency in science [2]. Additionally, the increased quantity of research data created a strong demand for suitable infrastructure: hardware, software, data management policies and other supporting documents and, of course, human resources for supervising the process of research data management. Suitable infrastructure, as the most crucial component, provides support to scientists, helping them focus on research itself rather than on technical and administrative aspects of research like manipulating large quantities of data.

Although science has been technically and structurally advancing through the second part of the 20th and the beginning of the 21st century, activities related to research data in digital format still lack the ease and speed with which researchers could create, collect large, complex datasets and manage them so they could be openly available. Due to the lack of adequate human (professional), technical (infrastructural) and document (guidelines and policies) support, researchers fall behind in the development and acquisition of knowledge and skills necessary to ensure data quality, integrity, shareability, discoverability and reuse over time [3]. Furthermore, researchers are not always able to spend enough time on research data management, while at the same time they neglect other activities. "Managing research data is time-consuming, costly and tedious, requiring additional resources that are not available to all researchers" [4] (p. 23). To achieve better and easier research data management with the aim to provide open access to research data resulting in broader availability and accessibility of research data and better cooperation between individual researchers, academic institutions and society must build uniform support to all researchers, which includes necessary technical infrastructure (individual, institutional and national), research data management policies and guidelines and training for researchers in research data management procedures. All these activities require a choice of good technical resources, time, good organization, professionally trained human resources (in IT and information sciences) and substantial long-term funding. The outcome of these activities will create a difference between research communities, those who are able to manage research data and those who are not.

This paper focuses on the management and use of data created by the Croatian scientists working in all scientific disciplines. Research data are "at the very heart of the knowledge life cycle and are a central ingredient to the scholarships of discovery, integration, teaching, engagement" etc. [5] (p. 345). The aim of data management is not only to facilitate the long-term preservation of research data but also to make these data available for two crucial activities: possible sharing and possible reuse by interested scientists. The latter activity adds most value to research data in general. Providing access to research data is achieved mostly by sharing research data with other people, directly upon their request or by providing access in institutional general purpose digital repositories or in specialized data repositories.

2. Materials and Methods

2.1. Research Data Management, Data Sharing, Data Reuse

In a growing data-intensive world, it has become difficult to assess the current volume of data created by vast number of industrial, personal and scientific endeavors, let alone predict future volumes of created data. Yet, there is a projection according to which, by 2025, global data volume will reach 175 zetabytes [6], a volume that will require meticulously created management procedures; otherwise, data will be lost, regardless of their origin or purpose. The main origin of data today is digital technology, the proliferation of which resulted in the production of big volumes of data. In the academic community, data have become an integral part of daily research processes and are more frequently counted as a standard research output [7], thus becoming a strategic commodity as well as a starting point for activities such as data sharing and data reuse (secondary analyses and new research).

Data sharing has become a symbol of open science. It promotes the transparency of research [8], provides evidence of a proper research, adds content to services such as data archiving, enables reuse (secondary analysis and comparative research), generates new research questions and results in new findings from the same data, thus creating value for money and added value [9–11]. It can inspire new and multiple perspectives [12] and enables the quality of the research through seamlessness and documentation [13,14]. Provision of data for the research quality control was a focus of the paper by Askarov, Doucouliagos, Doucouliagos and Stanley [14], in which the authors investigated publication bias and questionable research practices and they found out that data sharing and reuse may have reduced inflated statistical significance and decreased publication bias. Statistical significance was produced by authors wanting to make their paper appear more significant than it was, to be able to publish their research. Data sharing may be a tool to suppress these issues, at least partially.

Data sharing has been a holy grail of modern science. In 2023, data sharing is still not a universal activity in science, and it is burdened by barriers presented by individuals or institutions. As Khan, Thelwall and Kousha [7] point out, there have been many studies of data sharing and reuse in narrow contexts but there are no substantial science-wide research studies in this topic due to disciplinary differences. For instance, in the biotechnology sector, "individual privacy as well as intellectual property concerns often stand in the way of sharing data" [15]. Other problems include the time needed to share data effectively and fact that shared data are rarely used [7].

Successful research data sharing has technical and financial prerequisites. Technical prerequisites (personal computers, high-bandwidth Internet connections, capable storage servers) must be met so that the interested researchers can access data. Continuous funding is another prerequisite for facilitating future data reuse. The costs are related to datasets' size, complexity, different data types, metadata and documentation about the data, data quality, reuse value of data (so called "hot" and "cold" data) [16] and access control to data [17]. There are also two big categories of data that should be considered—qualitative and quantitative; both require different kinds of preparation for use [9]. Data management exists to ensure that data are "findable and accessible to both designated users and reusers, on a day-to-day basis" [16] (p. 1). However, in real life, researchers encounter different problems like diverse devices and diverse virtual places that contain digital content fragmentally, due to the fast accumulations of digital content shared [18].

The second important activity, research data reuse (a result or consequence of data sharing) includes the reproduction and verification of past research, making the results of funded research available; it supports efficiency and collaboration in research [10], interdisciplinarity and enables more frequent citation [7]. It helps in generating new questions based on the existing data and, most generally, make the advancement of science possible [19]. One of the biggest if not the biggest goal of research data reuse is to introduce reproducibility as a research quality criterion by acknowledging "the strengths and weaknesses of different ways of validating results and learn as much as possible from the methodological precepts that guide different parts of science" [20] (p. 142). Despite many efforts and initiatives in the scientific community and outside of it, reproducibility of research remains a substantial and unsolved problem in modern science [21].

Today, digital data management and related activity—data reuse—have become interconnected and essential activities in academia and elsewhere as the amount of data grows exponentially with and projection that the amount of data will only grow in near future.

2.2. Data Sharing Benefits, Motivation and Obstacles

The benefits resulting from the sharing the research data for the research community include data discovery, reuse, validation and verification of data [5]. The motives to share data include journal publishing pressure, normative pressure, perceived effort, pressure by funding agencies, perceived career benefits and scholarly altruism [22].

There are also reasons why researchers do not like to share their research data. Fecher, Friesike and Hebing [10] pointed out that research data are still not common knowledge because researchers have fears and doubts about data sharing including endangering the right to publish their research results first and the possibility of data misuse. In addition, publications that publish research data lack sufficient formal recognition for this activity, and there are also no incentives for sharing research data, so researchers remain incentivized not to share data. The lack of incentives for acknowledging and crediting researchers for sharing their own data and citing others' research data remains an unsolved problem [23]. Moreover, the authors of research data claim that other researchers cannot use their data properly because data can only exist in the specific context of their creation and, without the methodologies and ontologies adopted at the time of creation, other researchers cannot adapt data into their new research (projects) [23]. Lin Yoong, Turon, Grady, Hodder and Wolfenden [24] (p. 18) singled out the following problems to data sharing: "review access (e.g., located behind a paywall), logistical issues (e.g., lack of metadata, standardized reporting of measures, challenges with accessibility and data quality), motivational barriers (e.g., lack of author incentives), legal impediments (e.g., issues around ownership of data, intellectual property [IP]) and ethical concerns". In addition to the previously mentioned reasons (which sometimes overlap between authors), Mallasvik and Martins [12] compiled additional reasons like unavailability of funds or poor levels of knowledge regarding adequate formats and reusability, lack of recognition for those who willingly engage in research data sharing, high financial costs, uncertainties surrounding loss of control intellectual property rights and potential threats to national security.

Lewis [25] listed the rewards of good management of research data including significant potential benefits for academic research itself:

- The ability to share research data, minimizing the need to repeat work in the laboratory, field or library;
- Ensuring that research data gathered at considerable cost are not lost or inadvertently destroyed;
- The retrieval, comparison and co-analysis of data from multiple sources can lead to powerful new insights;
- The ability to verify or repeat experiments and verify findings, particularly important amid growing national and international concern about research integrity;
- New research themes—and in particular cross-disciplinary themes—can emerge from the re-analysis of existing data or comparisons with new data; increasingly, data may become the starting point for new research as well as represent an output from current research.
- If at least some of these issues were resolved, researchers would be prepared to share data if there were rewards for doing so [26].

2.3. Data Storing and Archiving

A prerequisite of achieving high reproducibility of research is reliable, long-term access to digital content [27], which is often missing or neglected. This long-terms access to research data is now commonly required by publishers, academic institutions and research project funding agencies [7,13,28,29]. However, research data are not always widely available for reuse as data sharing is not fully appreciated by researchers across all disciplines [2], restricting the reuse of data.

To be able to share research data, one must store and possibly archive them (long-term storage). Data archiving has become essential since the early days of personal computers and continues to be one of the challenges for modern science. The main goal of data archiving is to make quantitative and qualitative research data available for reuse.

Research data can come in different types: in open or controlled forms that include raw data, research data, sensitive data, government data and big data [30].

Sometimes, data are used only once and only by authors who collected data, interpreted and used them in an article, a report or a conference paper. After the publication of a journal article, conference paper or a book chapter, data may become hard to find as they were stored on scientist’s personal computer, external hard disk and elsewhere where data are not widely available (online). Nowadays, in the era of Big Data, data storing and archiving has become even more important because data can be easily lost and therefore become unavailable. This is especially true for older data collected, described and stored in places other than institutional, national or other digital repositories.

Furthermore, as previously noted, “scientific publications increasingly require that the data relevant to an article be available through archives” [13] (p. 6). On the personal level, personal computing users continue to experience catastrophic personal data loss [31].

3. Research Study

3.1. Research Design

The purpose of this research study was to explore current sentiments of the Croatian scientists about three aspects of use and management of research data, which were also research questions this study aimed to answer:

Q1: Do the Croatian scientists use research data of other scientists?
Q2: Do the Croatian scientists offer access to their research data?

Q3: What are the modes of storing research data?

The main hypothesis of this research is that the Croatian scientists are only moderately ready for data sharing and data reuse, which also only partially fulfils their research mission in society.

3.2. Research Instrument

To collect data about the current sentiment of the Croatian scientists about other scientists' and their own research data, an online questionnaire (Appendix A) was designed. The questionnaire consisted of 25 closed-type questions and three open-type questions, a total of 28 questions.

The research was initiated by sending invitations to the mailing list of the Croatian scientists and by asking scientists to send the same invitation to their colleagues (snowballing). The research used a convenience sampling method. This type of sampling was used as it was not feasible to divide members of the mailing list according to their age, research experience or other criteria. The findings, especially the demographics data, helped in differentiating scientists who participated in this research.

The invitation for participation in this research was sent by e-mail to the mailing list of the Croatian scientists administered at the "Ruđer Bošković" Research Institute in Zagreb, Croatia. The mailing list included 15,000 scientists, postgraduate students, professional associates, librarians and other employees from the system of science and higher education of the Republic of Croatia, who at some point during participation in various conferences, workshops, through consent in the Croatian scientific bibliography "CROSBI" [32] or through the application form subscribed to the mailing list and received the contents sent to it. According to the Croatian Research Information System [33], which quoted the Register of scientists and artists of the Republic of Croatia created by the Ministry of science and education of the Republic of Croatia [34], 29641 scientists were listed in the register on 19 April 2024.

The research started on 28 June 2023, and the access to the questionnaire was closed on 31 August 2023.

A total of 650 respondents participated in this research study by answering questions in the online questionnaire. Since only the respondents working in science and on science-related jobs were relevant to this research study (assistant, senior assistant, assistant professor, associate professor, full professor, full professor tenure, full professor retired, professor emeritus, scientific associate, scientific advisor, Ph.D. students), a total of 584 of 650 who participated in the study were filtered out) and their answers were further analyzed. It must be noted that not all respondents answered every question in sections of questionnaire related to them, so the number of answers per question varies from question to question. That means that 584 respondents equal approx. 1.97% of all Croatian scientists listed in the register of scientists and artists of the Republic of Croatia.

4. Findings

The findings are divided into four sections (A–D) in accordance with the structure of the questionnaire.

4.1. Use and Non-Use of Other Researchers' Data

The first section (Section A) of the research aimed at identifying whether the respondents used other scientists' research data or not.

A total of 584 respondents answered the initial questions about using or not using other scientists' research data. A total of 428 respondents (73.3%) used the research data of other scientists while 156 respondents (26.7%) did not use other scientists' research data.

As an addition to this question, the scientists in this research study were asked about their years of service. The scientists had been working in science for 20 years (median). These data about years of service were compared to the number of respondents who used research data of other scientists (not all respondents provided their years of service by choice): 1–10 years of service, 82 respondents used other scientists' research data; 11–20 years of service, 185 respondents used other scientists' research data; 21–30 years of service, 114 respondents used other scientists' research data; 31–40 years of service 65 respondents used other scientists' research data and 41+ years of service, 16 respondents used other scientists' research data. The years of service for the respondents who did not use other scientists' research data were the following: 1–10 years of service, 35 respondents did not use other scientists' research data; 11–20 years of service, 59 respondents did not use other scientists' research data; 21–30 years of service, 35 respondents did not use other scientists' research data; 31–40 years of service, 23 respondents did not use other scientists' research data and 40+ years of service, three respondents did not use other scientists' research data. Again, not all respondents provided data on their years of service.

The number of scientists in this research study who claimed they used other scientists' research data is high. It is impossible to back up such results with actual numbers of the exchanged research data because researchers use other scientists' data from different resources, sometimes internally (within the same lab, department or university) and frequently there is no exact proof of these activities. This is the reason why this result should be investigated further by conducting interviews with scientists.

A total of 153 respondents (3 out of the total of 156 who did not use other scientists' data left this question unanswered) did not use other scientists' research data for the following reasons (multiple answers were possible). Table 1 shows the detailed reasons for not using other scientists' data. Predefined reasons were offered to the respondents. About three-quarters of the respondents (from those who did not use other scientists' data) did not have a need for other scientists' data, while other respondents encountered different obstacles like paywall, membership, passwords or licenses. Such obstacles have usually been met by scientists in recent decades and they have caused the inability to access published papers and books. Now they have been extended to research data.

Table 1. Not using other scientists' data (N = 153).

Not Using Other Scientists' Data	Respondents (N)	Percentage %
I did not have need for other scientists' research data	120	78.4
Access to research data was restricted by a paywall	16	10.5
Access to research data was restricted by membership in an academic institution, etc.	18	11.8
Access to research data was restricted by password	11	7.2
User interface was too complex	6	3.9
I had to agree to licenses and other terms	8	5.2
User interface used a language I did not know	1	0.7
Other reasons	12	7.8

After answering this question, the respondents were asked to go to section D of the questionnaire related to storing research data and providing access to them.

4.2. Sending Requests for Research Data to Other Scientists

The next section (section B) of the questionnaire was dedicated to sending requests for research data of other scientists.

Direct contact with other scientists for gaining access to their research data was not the first choice of the respondents (N = 182) (Table 2). Another big block of results started with scientists who sent 2–3 requests (N = 163), while the rest of the respondents sent much less requests.

The respondents were also asked to list the sources from whom or from which they received research data (Table 3), suggesting that they used multiple resources for finding research data before accessing them.

Table 2. Sending requests for data of other scientists (N = 428).

Sending Requests for Data of Other Scientists	Respondents (N)	Percentage %
Did not send a single request for research data to other scientists	182	42.5
Sent one such request	52	12.1
Sent 2–3 requests	163	38.1
Sent 6–9 requests	31	7.2
Sent 10 or more requests	34	7.9

Table 3. Information on sources of research data (multiple answers were possible) (N = 419).

Sending Requests for Data of Other Scientists	Respondents (N)	Percentage %
Scientific publications (articles in magazines, books and proceedings)	379	90.5
Colleagues with whom I work directly (in the same department, etc.)	279	66.6
Colleagues working in scientific institutions outside Croatia	270	64.4
Digital repositories outside Croatia	270	64.4
Digital repositories in Croatia	203	13.7
Colleagues working in other scientific institution in Croatia	196	27.3
Colleagues with whom I work in the same institution	182	43.4
Other sources not listed here	16	3.8

Next, the respondents were asked to estimate the number of their own requests sent to other scientists to gain access to research data (Table 4).

Table 4. Estimation of the number of their requests sent to other scientists (N = 420).

Estimation of the Number of Their Requests Sent to Other Scientists	Respondents (N)	Percentage %
Did not send requests to other scientists	165	29.1
Sent one request	49	8.6
Sent 2–5 requests	142	25.0
Sent 6–9 requests	30	5.3
Sent 10 or more requests	34	5.99

Not all the delivered requests were answered positively: 0—16 respondents; 1—30 respondents; 2—22 respondents; 3—24 respondents; 4—five respondents; 5—eight respondents; 6—three respondents; 7—one respondent; 10—six respondents; 15—one respondent. Some respondents added their own answers instead of choosing pre-defined answers: "a few"—four respondents; "less than half"—two respondents; "half"—three respondents; "almost all"—22 respondents; "all"—116 respondents

The next four questions were oriented toward estimating the importance of research data for different phases of research in general: acquiring ideas for new research (N = 580), preparation of research (N = 575), execution of research (N = 580) and verifying the quality of research (N = 579).

Figure 1 shows the importance of research data in four aspects of research: developing ideas for new research, preparation of research, implementation of research and finally, increasing quality of research. The respondents considered increasing quality of research as the most important aspect of research data over other aspects of use of research data.

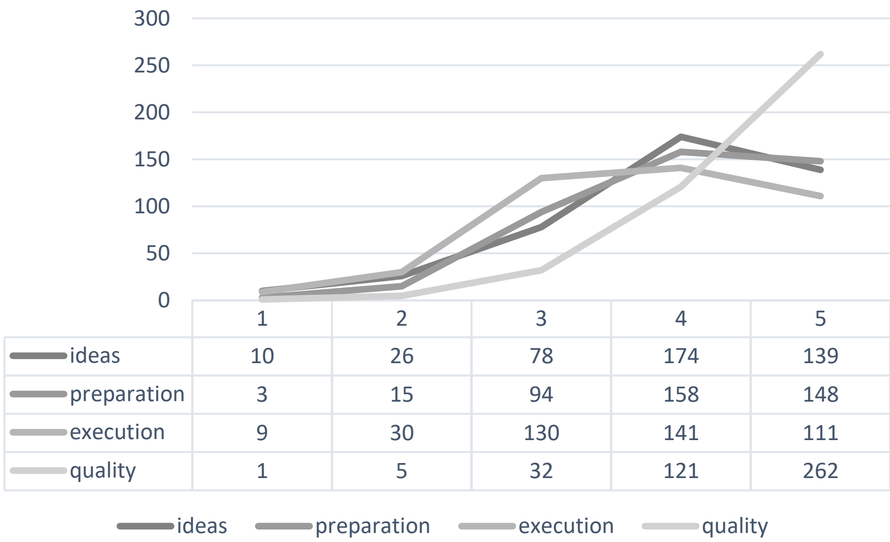

Figure 1. Importance of research data for different phases of research (1—least important; 5—most important).

In the last question in this section, the respondents were asked whether they ever tried to repeat the scientific research of another scientist based on their available research data (Table 5).

Table 5. Succes of repeating scientific research of another scientist (N = 423).

Success of Repeating Scientific Research of Another Scientist	Respondents (N)	Percentage %
No	253	59.8
Yes, I succeeded/I managed to get identical results	95	23.2
Yes, but I could not get identical results	75	17.7

The issue of reproducibility of research in science is a problem that has been well described in the scientific literature. Scientists involved in repeating one's research would most certainly like to obtain identical results to those in the original research/analysis.

This was the last question in this section that was aimed only at scientists who use other scientists' research data.

The next section (section C) was oriented toward the frequency of use of other scientists' research data as a template for new research, comparison with other research and quality control of research.

4.3. Providing Access to Own Research Data

The remaining part of the research study results included all the respondents, regardless of whether they used other scientists' research data or not.

The respondents were asked to estimate the number of requests they received for their own research data in the last five years (Table 6).

Table 6. Number of requests they received for their research data in the last five years (N = 584).

Number of Requests They Received for Their Research Data in the Last Five Years	Respondents (N)	Percentage %
One request	56	9.6
2–5 requests	183	31.3
6–9 requests	46	7.9
More than 10 requests	49	5.0
Did not receive any request	254	43.5

Almost half of the respondents did not receive any request from other scientists for their research data, while over half of the respondents (cumulatively) received one or more requests.

The next part of this research study was oriented toward providing access to research data for other scientists (the second part of the questionnaire).

In addition to the information found in Table 7, the respondents (N = 459) were divided according to their working experience (years of services), regardless of the mode of providing access to research data: 1–10 years of service, 82 respondents opened access to their research data; 11–20 years of service, 169 respondents opened access to their research data; 21–30 years of service, 127 respondents opened access to their research data; 31–40 years of service, 69 respondents opened access to their research data and 40+ years of service, nine respondents opened access to their research data. Next, the respondents who did not open access to their research data (N = 152) were divided according to their years of service: 1–10 years of service, 35 respondents did not open access to their research data; 11–20 years of service, 60 respondents did not open access to their research data; 21–30 years of service, 36 respondents did not open access to their research data; 31–40 years of service, 19 respondents did not open access to their research data and 40+ years of service, two respondents did not open access to their research data.

Table 7. Providing access to research data for other scientists (N = 640).

Providing Access to Research Data for Other Scientists	Respondents (N)	Percentage %
Access to all their research data without restrictions	186	29.1
Did not provide access to research data	157	24.5
Partial access to their research data without restrictions	148	23.1
Access to their research data in some other way not listed in pre-defined answers	120	18.8
Partial access to research data under certain conditions (IP address, password, etc.)	21	3.3
Access to all their research data with some restrictions (IP address, password, etc.)	11	1.7

While scientists shared their research data partially or fully, they also identified problems they encountered or feared encountering during the sharing of their own research data with other scientists (Table 8).

Table 8. Research data sharing problems (N = 430) (multiple answers were possible).

Research Data Sharing Problems	Respondents (N)	Percentage %
Fear of misuse of your research data in the form of idea theft	135	31.4
Excessive consumption of time	128	29.8
Fear of misuse of data of your research data in the form of theft of authorship	112	26.0
Lack of research data sharing infrastructure	110	25.6
Technical problems when sharing scientific research data	106	27.0
Lack of knowledge about how to share information about other scientists' data	99	23.0
Fear of misuse of your research data for commercial purposes	70	16.3
Costs of storing and sharing research data with others	44	10.2
There was no problem	27	6.3
Law restrictions and GDPR	5	1.2
Instead of research data, published works were shared	4	0.9
Improper or lack of citations	3	0.7
Research data were published in journals	3	0.7

Research data sharing depends on the good will of scientists, but it also depends on a potential system of recognition received for this activity.

Receiving recognition for sharing research data is one of the most important moments in scientists' careers, as it acknowledges scientists' efforts in certain areas. Table 9 shows that almost none of the respondents received a recognition for sharing their research data, which does not motivate scientists to start sharing their research data in the future.

Table 9. Recognition received for sharing research data (N = 488).

Recognition Received for Sharing Research Data	Respondents (N)	Percentage %
Received recognition or an award once	9	1.8
Received recognition several times	22	4.5
Never received recognition	457	93.7

The results presented in Table 10 indicate the awareness of practical aspects of opening access to research data like researchers' visibility, creating partnerships, transparency, quality and citations, which are benefits found at the top of the list (first five choices). Advancement in academic career and receiving recognition for opening/providing access to research data were least selected by the respondents. The complete lack of recognition or inadequate recognition for researchers for opening access to their research data was indicated in the previous question, and the same answer in this question was ranked very low and perceived to be less important by the respondents in this research study.

Table 10. Benefits of opening access to research data to other researchers (N = 457) (multiple answers were possible).

Benefits of Opening Access to Research Data to Other Researchers	Respondents (N)	Percentage (%)
Increasing your visibility in the scientific community	348	76.2
Creating partnerships in the preparation and implementation of scientific research	324	70.9
Increasing the transparency of scientific research	306	67.0
Increasing the quality of new scientific research	277	60.6
Increasing the citation of your scientific papers and scientific research data	249	54.5
Inspiration for starting new scientific research	237	51.9
Increasing the responsibility of scientists for conducting scientific research and presenting the results of that research	204	44.6
Confirming the accuracy of your scientific research results	201	44.0
Reducing the burden on scientists by using already existing scientific research data	134	29.3
Spotting mistakes in the scientific research of other scientists	117	25.6
Obtaining funds and/or equipment for the implementation of new research	84	19.0
Advancement to a higher scientific title based on storage activities and sharing of scientific research data	68	14.9
Receiving an award or recognition	34	7.4
Other	6	1.3
I see no benefit in providing access to my research data	5	1.1

To be able to provide access to research data, researchers must be offered some type of training/education about the process of research data management.

Based on the results in Table 11, researchers should be offered education about research data management if the scientific community in general expects them to share their research data on a wider scale.

Table 11. Training/education about the process of research data management (N = 455).

Training/Education about the Process of Research Data Management	Respondents (N)	Percentage (%)
Live lectures	24	5.3
Live workshops	24	5.3
University course	4	0.9
Live course	11	2.4
Webinars	71	15.6
Did not receive any of education about research data management	321	70.6

The next section (section D of these findings and the third part of the questionnaire) in the research study was dedicated to data archiving, a general and crucial precondition for data sharing and data reuse.

4.4. Research Data Storing and Archiving

The first question in this section was about devices or places for storing research data. Table 12 suggests that the respondents store their research data most frequently on their own computer at work, which is potentially very dangerous in the case of computer failure. Additionally, they stored research data on network drives in the cloud, which can also be dangerous if the network connection is lost, in the case of a security breach or due to another type of failure to access the data. Storing research data on offline external drives (and possibly on different locations) is a much better solution than storing data only on one's computer at work or on a shared computer. Digital repositories are not so popular, while there is a growing number of general types of repositories and data-only repositories worldwide available to scientists from different countries.

Table 12. Storing research data (N = 428) (multiple answers were possible).

Storing Research Data	Respondents (N)	Percentage (%)
On your own computer at work	255	59.6
On a network drive in the cloud	126	29.4
On an external hard drive	114	26.6
On an external SSD	48	11.2
In the institutional digital repository	46	10.8
On a shared computer at work where they store the contents of scientific research	30	7.0
I do not independently store scientific research data	8	1.9
On optical media	6	1.4
On a shared computer at work where they store the contents of scientific research	3	0.7

File format is a highly important element in research data archiving. The choice of data file format (Table 13) depends on the area of science in which different devices are used for the acquisition of data (by taking a record of a phenomenon, by recording measurements, etc.). Table 13 shows the great versatility of file formats. Some of them are standardized and appear in all areas of science, while some can be found only in particular areas of science and relate to some type of laboratory instrument paired with a computer, etc.

Time spent on data archiving is one of the biggest time eaters when considering a scientist's (monthly) workload. The results in Table 14 show that more than one-third of the respondents spend less than one hour monthly on data archiving, and that more than three-quarters of the respondents (cumulatively) spend up to 5 h monthly on data archiving. While the time spent on data archiving may differ from one research area to another and may depend on the type of research, the results show that more than three-quarters of the respondents do spend up to 5 h a month on data archiving, which is a positive result.

Table 13. File formats of research data (N = 428).

Research Data File Formats	Respondents (N)	Percentage (%)
Text files (TXT, DOC, DOCX, ODF, XML, PDF itd.)	399	93.2
Still pictures (TIFF, JPEG, PNG, SVG itd.)	268	62.6
Datasets (TSV, CSV, XLS, XLSX, XML, JSON itd.)	200	46.7
Video (MPEG4, MPEG2, QuickTime)	65	15.2
Geospatial data (ESRI, OGC, Geo PDF, GEOTIFF, etc.)	44	10.3
Sound (PCM, AIFF, MP3 itd.)	41	9.6
Other formats and applications related to specific formats like: .fasta, .abi; databases; BIN, CCS, MAT; simulator files and program code; Dwg, Excell, grib, NetCDF and other binary files; LOG, FCHK, CIF, SDF, TRJ, mgf, raw NMR specters (FID); NVvivo software; opj; various output formats of specific software; different programming languages; spss (multiple answers); SQL (dump); various database backup formats; statistical software files; Web GIS baza databases; XLS SPW	25	5.8
None of these formats	5	1.2

Table 14. Time spent on research data archiving (N = 623).

Time Spent on Research Data Archiving	Respondents (N)	Percentage (%)
Less than an hour	251	40.3
1–5 h	248	40.0
6–10 h	56	9.0
More than 10 h	32	5.1
I do not spend any time at all archiving the data of my scientific research	58	9.3

Data archiving requires knowledge about online or offline storage systems, file formats, metadata creation for data description and institutional policies for data archiving. The Croatian scientists were asked to rate their knowledge about research data archiving. A total of 644 respondents provided answers on a scale from 1 (no knowledge at all) to 5 (excellent knowledge). The results in Table 15 indicate that they acquired a certain amount of knowledge about data archiving but there is still space to reach a more advanced level of knowledge.

Table 15. Rating one's own knowledge about research data archiving (N = 644).

Research Data Archiving Level of Knowledge	Respondents (N)	Percentage (%)
1	42	6.5
2	173	26.9
3	271	42.1
4	129	20.0
5	29	4.5

5. Discussion

Empirical research studies of this type are a good base for solving different problems in research data management and could enable comparative analyses of conditions for work in different areas of science.

The results of this research study on the Croatian scientists identified several problems in use and management of research data. Roughly three-quarters of the respondents claimed they used other scientists' research data, which is a very good result. Still, they ran into different obstacles like paywalls, memberships in institutions or technical issues, which are all globally present problems that remain unsolved. Therefore, they require additional efforts on the side of different stakeholders involved in scientific endeavors.

Some obstacles, like paywalls, require cooperation with information aggregators in the commercial sector and are subject to long-term negotiations with commercial publishers. Technical issues are more easily solved but can sometimes be expensive.

Generally, some of the encountered problems are local and infrastructural and can be solved rather easily (e.g., digital research data repositories), while other problems are global and require more money, time and effort to be solved on the international level (e.g., publishing fees and research data storing as a supplement to books and articles).

Almost half of the respondents did not obtain data by sending requests to other scientists to access their data, whether they did not have a need for research data or did not receive any answer from the scientists to whom they sent requests. This latter problem could be solved by storing data in open data repositories to alleviate the problem of spending too much time on direct communication with other scientists.

The use of other scientists' research data by a larger number of scientists is practical, as a single researcher cannot discover all the problems present in some areas of research.

Also on the practical side, most of the research data that the respondents use in their analyses or new research come from their colleagues from the same department or institution, who are easily accessible and are reliable sources of research data. Research data also come from colleagues from outside the country with varying but mostly positive outcomes.

This research study showed that the Croatian scientists consider research data to be important in several cases: for obtaining ideas for new research, its preparation and execution, which is expected (if one uses research data as a starting point). The most important quality of research data for the respondents is that they are a means to increase research quality as they view research data as tools for verifying and increasing research quality. Regarding the problem of bad reproducibility of someone's research, it has been extensively addressed in the scientific literature but the solution to this problem has not been found yet. One evident reason is the need for hyperproduction of scientific output in the form of published books and articles as proof of one's scientific abilities. The hyperproduction diminishes the research quality and focuses on bureaucratic criteria for academic advancement. A growing number of research studies therefore remain irreproducible due to different problems related to low quality, which was partially confirmed by this research study. A significant number of researchers in this research study did not try to reproduce someone's research by using his/her research data, while one-quarter of the respondents claim that they managed to reproduce research and obtain the exact same results. Clearly, the results are not good.

Archiving data is another big and important topic in global science covered by this research study. The Croatian scientists who participated in this research study store research data on their own desktop computer, which could lead to a disaster in case of hardware failure. There are also other technical solutions for storing research data other than desktop computers like cloud infrastructure and external drives, each with its own problems, but they are still more reliable for long-term storing/archiving research data than desktop computers used by one or even many scientists. One possible solution is that cloud infrastructure could be better marketed to scientists.

Knowledge about data archiving has not yet reached a desirable level at which scientists will have advanced knowledge on this topic. Their knowledge is currently at an intermediate level. In Croatia, scientists have an opportunity to store research data in the national digital repository system, specially made for the Croatian academic community.

The proper storing of research data enables data sharing and data reuse. However, data sharing is not a straightforward process since there are many administrative, legal and technical obstacles and fears like misuse of research data, excessive consumption of time while sharing data to other people, idea theft, etc. These are very serious problems that are present globally in academic communities and remain unresolved. The same problems are present in the Croatian academic community and were recognized by the scientists participating in this research study. Another area that can be further researched is the benefits of opening research data to other scientists. The benefits were also clearly recognized by the respondents, but are hardly present in their daily work, and this is especially true for receiving reward for data sharing, which is a practically non-existent occurrence.

Finally, education on how to manage research data has become necessary, yet close to three-quarters of the respondents did not receive any form of education. Education in research data management will help them to overcome obstacles and spend less time on research data management.

This research study confirmed the hypothesis according to which the Croatian scientists who participated in this research study are only moderately ready for data sharing and data reuse, which also only partially fulfils their research mission in society. They will have to put more effort to achieve better results in research data management to make data sharing and data reuse more easily doable, but they should also receive recognition and rewards for doing so. This study also provided answers to all three research questions, as discussed in this part of the paper.

6. Conclusions

Research studies on research data management have now become common. While there is global interest in making research data easily obtainable, there are also local particularities that still block easy data sharing and reuse. Today, we know more about the role of research data in designing and executing new research than we knew yesterday, but we still need more marketing on research data management processes and infrastructures supporting scientists. Science is in transition toward open science, and every development that helps scientists to better and more broadly communicate the results of their research is valuable. This research study on the Croatian academic community shows that the Croatian scientists are partially ready for open science. The presumption is (which should be further researched) that those scientists who are collaborating with their colleagues outside Croatia and sharing and using the same datasets they created are more open to the idea of data sharing and data reuse and are probably actively participating in open science.

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Appendix A

Questionnaire

(1) In general, until the moment of your participation in this research, have you used data (regardless of their type) of scientific research by other scientists for the purposes of your scientific work?

- (a) Yes, I use data from other scientists and scientists from their scientific research (go to question 3)
- (b) No, I do not use the data of other scientists from their scientific research (mark the reasons for a negative answer in the next question)

(2) If your answer to the previous question was negative, please choose the reasons for not accessing scientific research data of other scientists. AFTER THIS QUESTION GO TO QUESTION 14!

- (a) Access to scientific research data required a password;
- (b) The interface of scientific research data sources is too complex to use;
- (c) The scientific research data source interface uses a language I do not know;
- (d) To access the data, I have to agree to license and other conditions that are unacceptable to me;
- (e) To access scientific research data, it is necessary to be a member of a certain institution, professional society, etc.;
- (f) I had no need to use the data of other scientists' scientific research;

(g) Access to scientific research data requires payment;
(h) Other:

Use of scientific research data

(3) Among the answers offered, choose the sources of scientific research data (EXCEPT DATA FROM YOUR OWN RESEARCH) that you use in your daily scientific work (it is possible to mark several answers).
   (a) The information I receive from the closest colleagues with whom I work directly (in the department, etc.);
   (b) Information I receive from other colleagues in the same scientific institution where I work;
   (c) Information I receive from colleagues in other scientific institutions in Croatia;
   (d) Information I receive from colleagues in scientific institutions outside Croatia;
   (e) Data that I find in digital repositories of scientific information in Croatia;
   (f) Data that I find in digital repositories of scientific information outside of Croatia;
   (g) Information that I find in scientific literature (articles in magazines, books and proceedings);
   (h) Other:
(4) According to your estimation, in the last 5 years, how many requests have you sent to a scientist/scientists to give you access to the data of their scientific research?
   (a) One;
   (b) 2–5 requests;
   (c) 6–9 requests;
   (d) 10 or more requests;
   (e) No, so far I have not sent a request to other scientists.
(5) If you sent one or more requests, how many of your requests were answered positively? The importance of scientific research data
(6) Mark the IMPORTANCE that the scientific research data of other scientists have on your consideration of ideas for starting your new research? They have no importance; 1 2 3 4 5 They are extremely important.
(7) Mark the IMPORTANCE that the scientific research data of other scientists have in the preparation of your scientific research? They have no importance; 1 2 3 4 5 They are extremely important.
(8) Mark the IMPORTANCE that the scientific research data of other scientists have in the implementation of your scientific research? They have no importance; 1 2 3 4 5 They are extremely important.
(9) In general, do you consider publicly available scientific research data of other scientists IMPORTANT for increasing the quality of scientific research? They have no importance; 1 2 3 4 5 They are extremely important. The purpose of using scientific research data
(10) How often do you use the scientific research data of other scientists to control the quality of their scientific research?
   (a) Constantly;
   (b) Most often;
   (c) Sometimes;
   (d) Rarely;
   (e) Never.
(11) How often do you use the scientific research data of other scientists for comparison with the results of your own research?
   (a) Constantly;
   (b) Often;
   (c) Usually;
   (d) Sometimes;

(e) Rarely;
(f) Never.

(12) How often do you take the data of scientific research of other scientists as a template for formulating research questions in your scientific research?

(a) Constantly;
(b) Most often;
(c) Sometimes;
(d) Rarely;
(e) Never.

(13) Have you ever tried to repeat the scientific research of another scientist based on the available data of their scientific research?

(a) Yes, but I could not get identical results;
(b) Yes, I succeeded/I managed to get identical results;
(c) No.

Enabling access to YOUR scientific research data to OTHER scientists

(14) According to your estimation, in the last 5 years, how many requests have you received from another scientist (or more) to grant them access to the data of your scientific research?

(a) One request;
(b) 2–5 requests;
(c) 6–9 requests;
(d) 10 requests and more;
(e) No, I have not received any request.

(15) If you received one or more requests, how many of these requests did you respond to positively?

(16) Have you provided access to the data of your scientific research at THIS MOMENT?

(a) Yes, I offer open access to ALL data from my scientific research;
(b) Yes, I offer open access to ONLY ONE PART of my scientific research data;
(c) Yes, I offer access to ALL the data of my scientific research with some restriction (password, IP address, etc.);
(d) Yes, I offer access to ONLY ONE part of the data of my scientific research with some restriction (password, IP address, etc.);
(e) I offer some form of access to the data of my scientific research that is not listed here;
(f) No, I have not provided access to my research data (partially or in full) (go to question 19!).

(17) If the answer to the previous question was POSITIVE, please answer whether you have ever received any form of recognition or award for providing access to the data of your scientific research to other scientists?

(a) Yes, but only once;
(b) Yes, more than once;
(c) No, never.

(18) What problems have you encountered when sharing data from your own scientific research?

(a) Excessive consumption of time;
(b) Costs of storing and sharing scientific research data with others;
(c) Technical problems when sharing scientific research data;
(d) Lack of knowledge about how to share information with others;
(e) Lack of data sharing infrastructure;
(f) Fear of data misuse of your scientific research in the form of idea theft;
(g) Fear of data misuse of your scientific research in the form of theft of authorship;

   (h) Fear of misuse of your scientific research data for commercial purposes;
   (i) Other:

(19) Providing access to the data of your scientific research to other scientists can be useful for:
   (a) Increasing your visibility in the scientific community;
   (b) Creating partnerships in the preparation and implementation of scientific research;
   (c) Obtaining funds and/or equipment for the implementation of new research;
   (d) Receiving an award or recognition;
   (e) Advancement to a higher scientific title based on storage activities and sharing of scientific research data;
   (f) Increasing the transparency of scientific research;
   (g) Increasing the responsibility of scientists for conducting scientific research and presenting the results of that research;
   (h) Increasing the quality of new scientific research;
   (i) Reducing the workload of scientists by using already existing scientific research data;
   (j) Inspiration for starting new scientific research;
   (k) Spotting mistakes in the scientific research of other scientists;
   (l) Increasing the citation of your scientific papers and scientific research data;
   (m) Confirming the accuracy of the results of your scientific research;
   (n) I see no benefit in providing access to the data of my scientific research;
   (o) Other:

(20) In the last 5 years, have you participated in any form of education dedicated to the management of scientific research data?
   (a) Yes, a live course;
   (b) Yes, a live workshop;
   (c) Yes, a live lecture;
   (d) Yes, Webinar;
   (e) Yes, a university course;
   (f) No.

Storage and archiving of scientific research data

(21) Where do you most often INDEPENDENTLY store the data of your scientific research?
   (a) On your own computer at work;
   (b) On a shared computer at work where they store the contents of scientific research;
   (c) To a network drive in the cloud;
   (d) In the institution's digital repository;
   (e) To an external hdd;
   (f) To an external SSD;
   (g) On optical media;
   (h) I do not independently store scientific research data.

(22) What file formats do you use to store the data of your scientific research?
   (a) Text files (TXT, DOC, DOCX, ODF, XML, PDF, etc.);
   (b) Images (TIFF, JPEG, PNG, SVG, etc.);
   (c) Video (MPEG4, MPEG2, QuickTime;
   (d) Sound (PCM, AIFF, MP3, etc.);
   (e) Datasets (TSV, CSV, XLS, XLSX, XML, JSON, etc.);
   (f) Spatial data (ESRI, OGC, Geo PDF, GEOTIFF, etc.);
   (g) None of the above formats;
   (h) Other:

(23) According to your estimation, how much time do you spend PER MONTH on archiving the data of your scientific research?
   (a) Less than an hour;
   (b) 1–5 h;
   (c) 5–10 h;
   (d) More than 10 h;
   (e) I do not spend any time at all archiving the data of my scientific research.
(24) Rate your level of knowledge about data archiving of scientific research. Completely without knowledge; 1 2 3 4 5 Excellent knowledge. Data on research participants
(25) In which field of science do you work?
   (a) Natural Sciences;
   (b) Technical sciences;
   (c) Biomedicine and healthcare;
   (d) Biotechnical sciences;
   (e) Social sciences;
   (f) Humanities;
   (g) Artistic area;
   (h) Interdisciplinary fields of science;
   (i) Interdisciplinary fields of art;
   (j) Other:
(26) Mark your gender.
   (a) Male;
   (b) Female;
   (c) I do not want to state.
(27) How much work experience do you have in jobs related to science?
(28) What is your current associate, scientific, scientific–teaching or artistic–teaching title? (Scientific–teaching professions choose only one answer!)
   (a) Scientific associate;
   (b) Senior research associate;
   (c) Scientific adviser;
   (d) Scientific advisor in permanent position;
   (e) Assistant;
   (f) Senior assistant;
   (g) Assistant professor;
   (h) Associate professor;
   (i) Full-time teacher;
   (j) Full professor in a permanent position;
   (k) Other:

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