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Meta-Research

Research Methods course

Master in Sound and Music Computing, Master in Intelligent and Interactive Systems, Master in Computational Biomedical Engineering, and Master in Wireless Communications

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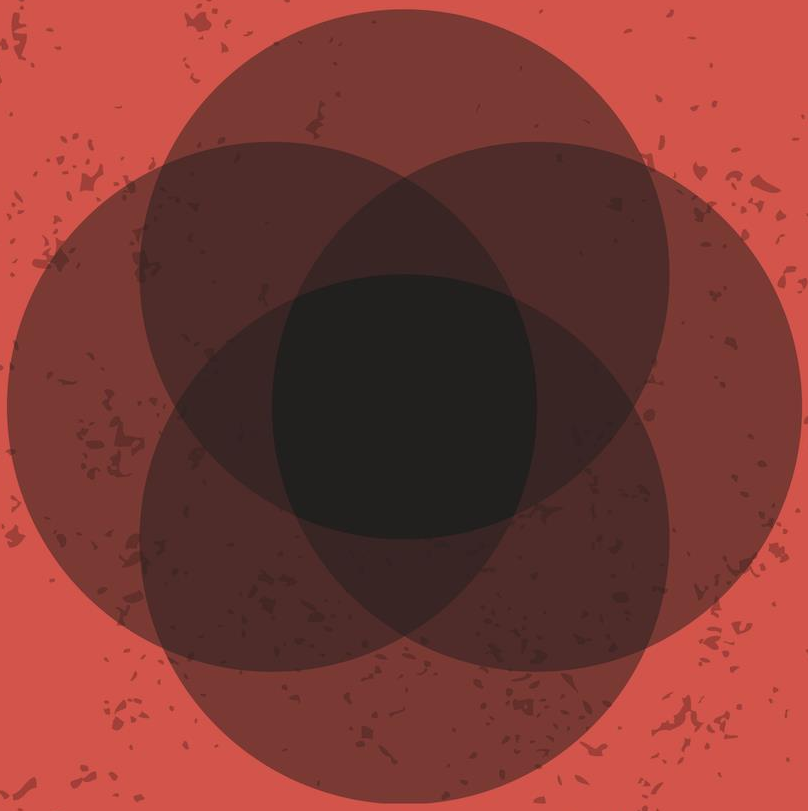
Preface

This document collects a selection of papers written by master's students in the context of the "Research Methods" course common to the Master's Programmes in Sound and Music Computing, Intelligent and Interactive Systems, Computational Biomedical Engineering and Wireless Communications, of the Information and Communication Technology Department at Universitat Pompeu Fabra, Barcelona, during the 2018-2019 academic year.

The papers were written as part of an integrative assignment entitled "Meta-Research", where students were expected to do a small piece of research about a transversal research topic. Students worked in teams and selected a topic, among the following suggested themes: Open Science, Social Impact of Science and Technology, Research-Industry Collaboration and PhD Process and Life. A refinement of the topic, the particular research questions to study and the methodology to apply were proposed by the students and discussed with the course educators in tutoring sessions. A total of 14 papers were written by the students and presented in the classroom. Assessment included peer-review by students during the presentations, through a conference management program, assessment by the educators, and self-assessment. The results from the peer-review were considered to recognize two of the papers with "Best Paper Awards". These papers can be read in pages 29 and 109.

MeRe 2018

META-RESEARCH CONFERENCE



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RESEARCH METHODOLOGY
UNIVERSITAT POMPEU FABRA

Contents

Qualitative FAIR principles analysis on generalist data repositories

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Abstract. Scientific data repositories are called in Open Science (OS) to implement systematic data stewardship practices to foster adequate scientific datasets collection, curation, preservation, long term availability, dissemination and access. However, an urgent need has been identified to improve the way these platforms deal with the management of data according to Open Data (OD) philosophy. In order to tackle this issue, a set of principles known as "FAIR" principles have been proposed in order to assist data publishers and stewards in their implementation choices. In this study, it is performed an in-detail analysis on the process of data sharing in widely used repositories with respect to fulfillment of the FAIR principles. For this purpose, it is used a qualitative approach, using metrics derived from these principles. We observed that the repositories implemented effective solutions to cover the FAIR principles, although there were some aspects which still need to be covered in most cases, especially in the Interoperability and Reusability categories.

Keywords: Open Science, Open Data, FAIR principles.

1 Introduction

Open Science (OS) can be defined as a new approach to do research based on cooperative work and new knowledge diffusion ways through digital technologies and new collaborative tools [1]. In the digital technologies and networks era, OS has achieved a considerable popularity amongst researchers, and currently many of them decide to openly share their data. Open Data (OD) is organized in *Scientific data repositories* [2] which are called in OS to implement systematic data stewardship practices to foster adequate scientific datasets collection, curation, preservation, long

term availability, dissemination and access [3], [4]. A robust digital infrastructure is essential to support proper data management and to ensure that data are preserved in a useable form for people other than the creators of the data [5]. Unfortunately, the existing digital ecosystem surrounding scholarly data publication prevents extracting maximum benefit from research investments [6]. Therefore, there is an urgent need to improve the infrastructure supporting the reuse of scholarly data [7]. Because of this, we identified the need to analyze the current OD repositories in order to see how they manage the process of data sharing. In fact, this has already been done using a variety of approaches and highlighting different features and aspects [3], [8]–[10].

On the other hand, the set of principles known by the acronym "FAIR", standing for Findable (F), Accessible (A), Interoperable (I) and Reusable (R); have been created to assist data publishers and stewards in their implementation choices [7]. FAIR is considered as the guiding Principles for data management in OD [7] (see appendix 2), and the awareness of FAIRness is growing every day thanks to communities as *FORCE11* [11] or to movements as the *GO FAIR Initiative* [12] launched by the *European Open Science Cloud* (EOSC), which aspires to turn FAIR into reality in collaboration with the *Open Science Policy Platform* (OSPP). Many researches try to share openly their data aiming to increase the citation impact of their papers [13], nonetheless, there is a gap between OD and the final consequent desired output. This gap can be explained because of some data sharing practices not being well established or standardized so as to meet with the characteristics of how must be ideally OS: FAIR. With many available dissemination channels for sharing data, researchers do not see a clear reliable value on OD, even more, they come to wonder about if the data could be corrupted since important information is missing. Understandably, there is a need in adding value to OD making it feasible for reuse as well as to be easily found, accessed and interoperated with many OS digital platforms in order to accelerate the research progress in the scientific community and to give full credit to data generators and creators (usually researchers).

The effectiveness and relevance of FAIR principles has been analyzed, as well as their application in practice [14]. However, we could not find any examples in the literature that described in detail how these principles are applied in actual repositories. In this work, we seek to know to which extent (and how) these principles are being applied in scientific data repositories. For that purpose, we evaluated a series of well-established general repositories that follow an OD philosophy using metrics derived from the FAIR principles. We also produced a detailed review on the kind of solutions repositories implement for each principle, as well as, the ones that may be lacking.

2 Materials and research methodology

2.1 Materials

We selected general Data Repositories (DR) recommended by Scientific Data Nature [6] and Pompeu Fabra University [15]: Zenodo, Dryad, Eudat (B2Share), Hardvard Dataverse, Data Base, figShare, 4TU Centre for research data and Open Science Framework (see appendix 1). From all repositories were collected their official information provided and the metadata associated to openly shared datasets. Microsoft Excel 2016 was used for results processing.

2.2 Research methodology

As the FAIR principles [7] (see appendix 2) are aspirational, meaning that they do not strictly define how to achieve *FAIRness*, metrics designed by *FAIR Metrics Group* (*FORCE 11)* which [16] follows a robust guideline [17], were selected to evaluate repositories. It should be mentioned that the specific way to measure each metric was not exactly followed, but rather was adapted for a more qualitative approach. In table 1 are defined the metrics associated to each principle with the evaluation criteria to classify the gathered information in four levels in terms of a categorical scoring: green (available), orange (almost all), red (not available), and blue (not clear).

The research methodology applied is experimentally historical since the evaluation is based on the information provided by the about, policies and documentation sections of finished repositories born from projects, as well as the collected metadata that already exists (appendix 4). Then a purely qualitative study is performed because within the categorical levels defined there is not any existence of a dependent variable that enables a mathematical analysis from a statistical approach. In Figure 1 is depicted the workflow of the methodology.

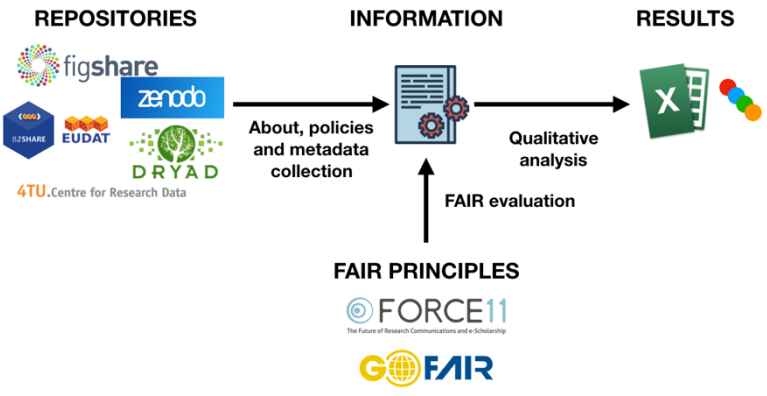

Figure 1. Methodology workflow. Collection and evaluation of the information.

We chose a qualitative method over a quantitative one because we found that the derived results could better address our research question, which is quite open, allowing to identify relevant aspects for each individual repository. One limitation of this methodology is that the results obtained cannot be considered as objective, but rather as orientative. This is a consequence of both the approach used and the limited resources available. We therefore aim to provide an insightful analysis about the "big picture" concerning data sharing in repositories, but we do not ensure the reliability of the particular metric assessment.

Table 1. Evaluation of FAIR principles. Each principle has different metrics with the evaluation criteria we based on for the repository's characterization in terms of FAIR. (*) and (**) are commented particularly in the results section because of their ambiguity.

Principle	Identifier	Metric Name	Evaluation criteria
Findable	F1	Identifier Uniqueness	The resource has a visible unique identifier (i.e. DOI, URN, IRI, Handle, etc.).
	F2	Attribute rich-information	Metadata has complementary attributes rather than just the title, creator and date.
	F3	Indexed in a searchable resource	Digital resource can be found by web-based search engines.
	F4	Resource identifier in metadata	The identifier is visible and explicitly included in metadata.
Accessible	A1	Standardized communication protocol to retrieve the data	Repositories use HTTP communication protocol.
	A2	Metadata Longevity	Metadata is still available even when the data have been removed.
Interoperable	I1	Knowledge Representation	Metadata is structured, ideally in a standardized way (it is comprehensible to the end user).
	I2	Use FAIR Vocabularies	Metadata themselves are FAIR. Appropriate knowledge-exchange format community-accepted.
	I3	Use Qualified References	Metadata include linksets related to metadata publications. *
Reusable	R1.1	Accessible Usage License	The repository states a license document for both data and its associated metadata, independently.
	R1.2	Detailed Provenance	There is additional documentation about how the data was created.
	R1.3	Meets Community Standards	Metadata follows standardized language and structure. **

3 Results

In figures 2 and 3, histograms are shown from the color-code evaluation (see appendix 3). While figure 2 shows results for each of the categories, figure 3 provides similar information for the individual principles within each category. In table 2 there is a description of the features implemented by the repositories with respect to the principles they fulfill.

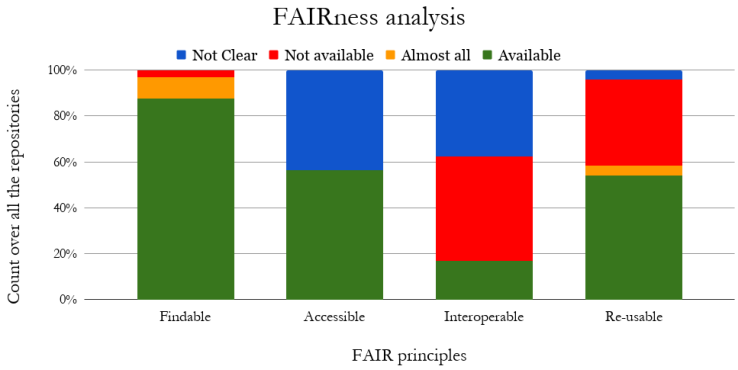

Figure 2. Summary of the results after the qualitative FAIRness analysis on DR.

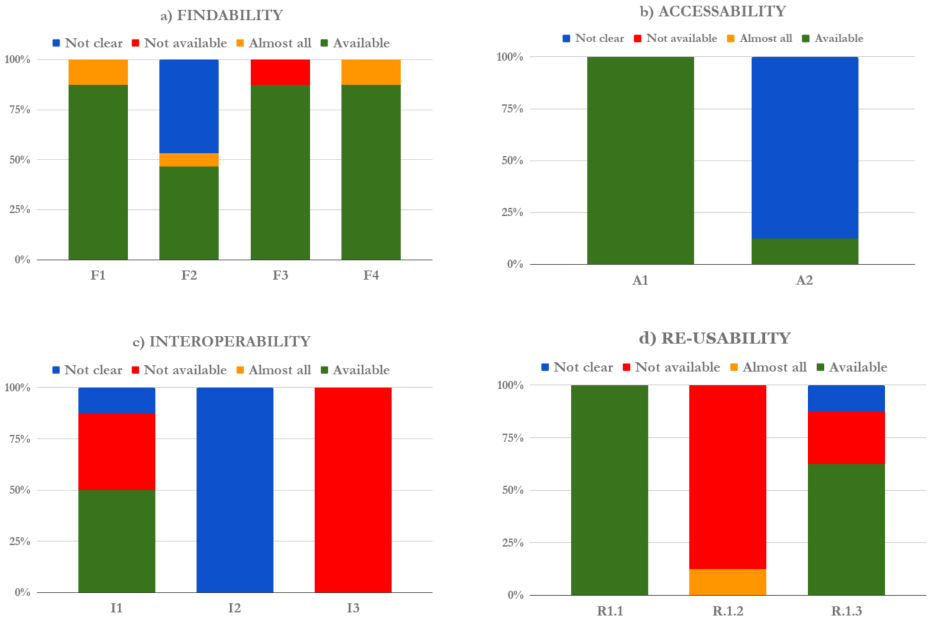

Figure 3. Decomposed FAIRness results per each principle.

Table 2. Relevant FAIR characteristics in analyzed repositories. Descriptions are based on metrics described in table 1. To see the categorical level of each metric for each repository, see appendix 2.

Repository	Findable	Accessible	Interoperable	Reusable
Zenodo	DOI identifier; OpenAIRE indexed	HTTP 200 communication protocol	Metadata in Dublin Core, JSON, DataCite and BibTex readable formats	Data under license; Dublin Core as accepted standard language for general purpose
Dryad	DOI identifier; Google indexed	HTTP 200 communication protocol	Metadata in Dublin Core readable format	Data under license; Dublin Core as accepted standard language for general purpose
figShare	DOI identifier; Google indexed	HTTP 200 communication protocol	Metadata in Dublin Core, DataCite, Endnote and BibTex readable formats	Data under license; Dublin Core as accepted standard language for general purpose
Harvard Dataverse	DOI identifier; Google indexed	HTTP 200 communication protocol	Metadata in Dublin Core readable format	Data under license; Dublin Core as accepted standard language for general purpose
e-Repository (UPF)	HANDLE identifier; Google indexed	HTTP 200 communication protocol	Metadata in Dublin Core readable format	Data under license; Dublin Core as accepted standard language for general purpose
Open Science Framework	DOI identifier; SHARE OSF indexed	HTTP 200 communication protocol	-	Data under license
Eudat B2SHARE	DOI and PID identifier	HTTP 200 communication protocol	-	Data under license
4TU – Centre for research data	ORCID identifier; Google indexed	HTTP 200 communication protocol	Metadata in RDF readable format	Data under license

As it can see in figure 2, most of the generalist data repositories follow the Findable and Accessible principles, nonetheless, there is a lack in the implementation of interoperability in metadata files and also a weak structure for reusability. It can be hypothesized that if these repositories, which are widely used and recommended, fail to cover some of the FAIR principles, it could be possible that if specific repositories were analyzed many more issues would be found.

Findability was in general achieved by most repositories. All of the repositories used a unique identifier (F1) which was a DOI domain in most cases. However, it could not be found the identifier in some of the datasets on OSF. Apart from the title, creator and date, metadata usually provided additional information such as keywords, subject and dataset description (F2). Besides, all repositories except for Eudat B2SHARE were indexed in a searchable resource (F3). Resource identifiers were included in the metadata (F4), although this was not always the case with OSF. Accessibility was also well implemented in most cases. All of the repositories analyzed use HTTP communications protocol (A1). Regarding criteria A2 (Metadata Longevity), it could only be found information for Harvard Dataverse, which specified that even in the case of deaccessioned data, basic citation metadata is always accessible.

Interoperability (I) and Reusability (R) were less often accomplished. Most of the repositories use a standard such as Dublin Core for the metadata (I1). We found criteria I2 (Use FAIR Vocabularies) very difficult to assess, since a clear definition could not be reached of what a vocabulary is and is not. For this reason, we decided to leave this field as unknown for all cases. Criteria I3 (Metadata include linksets related to metadata publications) was also challenging to evaluate thoroughly as it involves not only that the references to the resource are qualified, but also that there are qualified (described) references to other third-party resources. This second point is difficult to assess given that in almost all cases we were unable to find any datasets including references to other datasets, in which case we gave a negative mark. In the case of the UPF e-Repository, references to other resources were present in the (meta)data as an identifier, but had no complementary description. On the other hand, almost all repositories presented an accessible usage license (R1). However, none of them included detailed contextual information in a standardized way (R2). We also had some doubts concerning criteria R3. This criteria, as defined by the description available at the go-fair webpage, concerns whether (meta)data is published in a manner that increases its usability for the community (i.e. the (meta)data uses a standard recommended by the community). This would be very difficult to assess, given that our analysis has a general standpoint. Therefore, we decided to give a positive mark if a widely recognized standard such as Dublin Core (DC) was used, assuming that these kinds of standards comply with most domains. This was again the case for most of the repositories.

4 Conclusions

In the evaluation, we saw that, in general, repositories implemented effective solutions to cover FAIR principles. However, we observed a contrast between the rate of achievement of the four categories: Findability and Accessibility are globally covered since it is natural to be intrinsically implemented by the repositories. In contrast, Interoperability and Reusability are the most problematic ones, denoting that there is a lack of consensus on how metadata and data should be structured and standardized in the framework of OS.

We reached a conclusion that some of these principles involve a shared responsibility, that is, they do not depend solely on the framework itself but also on how researchers use this framework to provide useful metadata (e.g. by including qualified references and detailed information about the context surrounding the recollection of the data).

In this work we analyzed the application of the FAIR principles in some of the current most widely-used generalist scientific repositories. We consider that our contribution has been to provide a clear assessment of how recommended DR are performing in OS, as well as to provide some orientation on how data management practices could be improved, based on the shortages of current DR.

Further studies should focus on how to address these shortcomings in practice as well as to develop a more standardized framework for assessing data sharing practices. Concerning this second point, an interesting possibility would be to develop a software tool with implemented FAIR principles philosophy that could generate a FAIRness report from metadata files. This could be thought of as a help for researchers, in order to evaluate suspicious data in the world of OD, as well as for those responsible of implementation of the resources, as a way of identifying weak points in their frameworks.

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Appendix 1

Table 3. Data repositories evaluated.

Data repository	URL accessed in November, 2018
Zenodo	https://zenodo.org/
Dryad	https://datadryad.org/
Eudat (B2Share)	https://b2share.eudat.eu/
Harvard Dataverse	https://library.harvard.edu/services-tools/database-search
figShare	https://figshare.com/
4TU – Centre for research data	https://researchdata.4tu.nl/en/home/
Open Science Framework	https://osf.io/

Appendix 2

Table 4. FAIR Data Guide principles [7]**.**

FAIR principle	Description
To be Findable	F1. (meta)data are assigned a globally unique and eternally persistent identifier
	F2. Data are described with rich metadata
	F3. (meta)data are registered on indexed in a researchable resource
	F4. Metadata specify the data identifier
To be Accessible	A1. (meta)data are retrievable by their identifier using a standardized communications protocol
	A1.1. the protocol is open, free, and universally implementable
	A1.2. the protocol allows for an authentication and authorization procedure, when necessary
	A2. Metadata are accessible, even when the data are no longer available
To be Interoperable	I1. (meta)data use a formal, accessible, shared and broadly applicable language for knowledge representation
	I2. (meta)data use vocabularies that follow FAIR principles
	I3. (meta)data include qualified references to other (meta)data
To be Re-usable	R1. Meta(data) have a plurality of accurate and relevant attributes
	R1.1. (meta)data are released with a clear and accessible data usage license
	R1.2. meta(data) are associated with their provenance
	R1.3. (meta)data meet domain-relevant community standards

Appendix 3

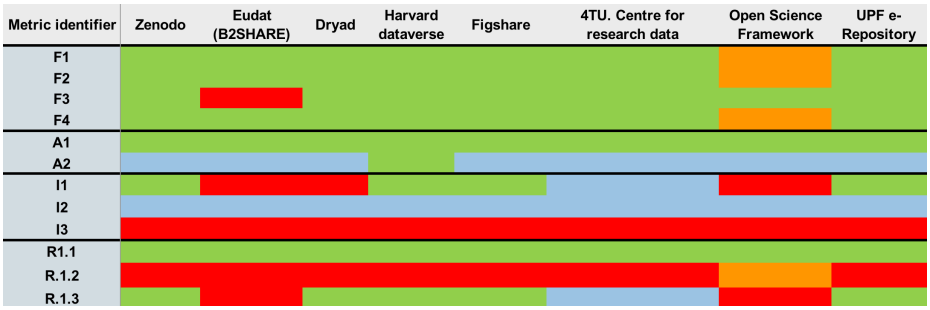

Figure 4. Categorical level for each metric evaluated from FAIR principles.

Appendix 4

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<?xml version='1.0' encoding='utf-8'?>
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http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="
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oai_dc.xsd">
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  <dc:creator>Mungall, Chris</dc:creator>
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Figure 5. Metadata schema example in Dublin Core format, within other formats analyzed.

A literature review about the difference in security for open source and proprietary source software - And its influence in Open Science

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Abstract. The number of projects that have at least one open source component is growing. There are a lot of concerns and different concepts regarding the stability and security that an open source projects offer. This research uses these ideas and compares the possible contradictions in order to shed some light on this controversial topic. The process took into consideration five papers and compared the different beliefs taking into consideration: the paper statistics, the user experience, pros and cons, the open source analysis and future work. The research was conducted in a way that it is easy to conclude that the open science world needs more collaboration and fewer myths.

Keywords: Open Source, Security, Software, Science.

1 Introduction

In this modern and fast-paced world, security is more important than ever. It is one of the fastest growing industries in the world. It includes things that are unseen but extremely valuable such as electronic data or e-data, for example, credit card details or government documents. Digital technology is now just a part of life. From online shopping to net banking and business to government infrastructure, digital technology plays a crucial role.

In the vast world of software products and projects, there are two main development models used to build software: Proprietary, where the source code is owned by a company and it is not publicly exposed; and Open Source Software (OSS), in which source code is published to the public and developers are licensed to modify and distribute it freely (according to some restrictions) [1].

Feller and Fitzgerald [2] explain the six conditions that outline OOS based on the Open Source Definition:

- The source code must be available to the user.
- The source code must be redistributable.
- The source must be modifiable, and the creation of derivative works must be permitted.
- The license must not discriminate against any user, group of users, or field of endeavor.
- The license must apply to all parties to whom the software is distributed.
- The license cannot restrict aggregations of software.

Due to the nature of the software development models, OSS and Proprietary Software, the development methodology between them present important differences [1] summarized in Table 1.

OSS	Proprietary Software
Development process is collaborative. The software is built by a large number of contributors.	Software development is done by a work team as part of a business project roadmap.
Work is not assigned. The contributors develop new code voluntarily.	Work is assigned to a defined development team.
Software design is flexible. Contributors make design decisions.	Software design used to be assigned by a team before the development phase.
No schedules, deadlines, or list of deliverables.	A business roadmap with delivery estimations are defined for the project.
No costs associated. No financial or monetary limits.	Projects are limited by financial boundaries and require resources management and costs analysis.

The importance of this study is backed by the 2018 Black Duck report [3]: currently for 96% of commercial applications there is at least one open source component. This not only provides an overview of the high usage of open source software in the industry but also on the high importance and impact it has regarding the overall security of the entire software industry.

This research aims to address this issue from the open source point of view considering all the myths, pros and cons that are actually associated with this kind of

software. A comparison between the security flaws and issues in a closed source software and open source will be the principal focus of this research.

A general idea that access to source code lets users improve system security is widely spreading. Limited tests indicate that for some cases, open source life cycles produce systems that are less vulnerable to non-malicious faults [4]. These findings are contradicted by other studies that argue that there is no empirical evidence that the particular type of software development is the primary driver of security [5]. A comparison table at the appendix section compares five different papers that were found relevant.

As security is one of the main focus of this study, a definition of software security is presented to help the reader understand this concept: Software security is the idea of engineering software so that it continues to function correctly under malicious attack [6].

2 Research methodology

For this study, a review method that compiles, analyzes and compares all the results and ideas that have been exposed in other sources will be used in order to check the ideas and see how everything correlates and impacts security in the systems. This was the chosen method since it has been shown that there are a lot of contradictions and different ideas about the topic. Although the purpose is trying to be as rigorous as possible, there is always a possibility of excluding some relevant research pieces that will be palliated by a deep research of the resource available.

Google Scholar and the web of Science were used in order to find data related to the open source software and its issues with security. Some of the keywords used were: “open source vs closed source”, “open source security” and “open source issues”. The Google search engine was also used: searching using keywords that involved “open source” and “security”. The criteria for taking into consideration the papers were how relevant they were about the subject. There was also a discussion about how many papers were used for the analysis.

The specific search conducted always included at least one of the following keywords: "open source", "security", "open source robustness" and "open source security". More than 100 results that might had some relevance were found, nevertheless, the sorting used was good enough for the purpose of the research. After analyzing titles and abstracts of the first 20 search results, the conclusion was that the papers more useful were the ones sorted first by the search engine default sorting. Several searches using plain Google were also conducted, analyzing the titles more relevant within the first 20 pages of the search engine. When a paper that had similar goals to this study was found, a verification check was conducted, in order to prevent plagiarism.

After the first round of papers, a new search was conducted based on the cited papers: there wasn't found any new paper to be taken into consideration.

3 Results

In this section, a comparison between different sources was made in order to evaluate the suitability of open source software/systems with respect to security. There were also compared arguments in favor and against open source security.

3.1 Peer Review

Supporters of open source systems argue that other programmers will review the code, given that it is openly published. These programmers will find problems on the code, even though they might not be looking for bugs. Usually, whoever finds the bug will find a solution to cover the problem. "Given enough eyeballs, all bugs are shallow" [7].

Advocates of proprietary software say that peer review argument is not valid because until a significant number of qualified people (developers) install the software and use it, many untrained users will simply have to trust the code. This leads to a question: considering that the source code is available to everyone, is the peer review an advantage?

3.2 Code Availability

Even though supporters of open source defend that the availability of the code for everyone helps increase security, advocates of proprietary software refute this argument, based on the principle that if these bugs are never found there is no security problem. Property software supporters argue that finding these bugs is easier when the source code is available, restricting access to the code will hide bugs and security flaws, improving the overall security.

There are not a lot of empirical and in depth studies comparing the security of open source and closed source software. Guido Schryen [5] compared published vulnerabilities of 17 widely deployed open source and closed source software using a wide range of software applications type: Browser (Internet Explorer and Firefox), Email client (MS Outlook Express 6 and Thunderbird1), Web Server (IIS 5 and Apache2), Office (MS Office 2003 and OpenOffice2), Operating system (Windows 2000, Windows XP, Mac OS X 10.x, Red Hat Enterprise Linux 4 and Debian 3.1) and Database Management (MySQL 5, Post-greSQL8, Oracle10g and DB2 v8). Schryen argues that the type of software is not the primary driver for software security. When comparing data related to the development of vulnerabilities disclosure over time, the severity of published and unpatched vulnerabilities and their severity when compared, Schryen did not observe any noticeable difference between the two types of software.

Despite this, Schreyer's studied proved that OSS seems to prevent *"extremely bad"* patching behaviors.

Based on these ideas of collaboration, teamwork and some kind of *greater good* view a comparison can be drawn between open source software and open science. There are several myths in need to be debunked that not only happen in open source software but can also be found in the vast field of open science. There is a need for more collaborators in order to grow and make science a more open place where everyone in need can benefit from it and at the same time continually helping to improve it.

4 Conclusions

This research has evaluated several of the advantages, disadvantages and myths about open source development. A comparison was shown between different approaches for examining what it is called *security*. The analysis of peer review and code availability and the respective advantages were useful in order to analyze the context of open source. These sections were found to be the most contradictory: some authors argue that it could be good or that it can actually be bad, further research is required. There are some counter posed ideas in both of them but the actual conclusion seems to be a philosophical question rather a technical one.

The research was focused on analyzing five different papers: each one having their own approach, context, conclusion and even uncertainties. The analysis was conducted allowing comparisons of the user experience and the analysis of the respective authors. Conflicting ideas between the papers were noted. The important factors for the comparison and the analysis were the following:

- Conclusions: The summary of the papers conclusion showed that there is no clear difference between the security in proprietary source software and open source software and each time the proprietary software includes more open source components.
- Open Source software development process analysis: The peer review, the code availability and discoveries in both systems show that after all the different approaches in all of them the results are that it does not matter if the project is open source or closed source regarding the security.
- User Satisfaction: The user satisfaction according to security has been higher in open source systems in comparison to proprietary source systems.
- Cons And Pros for security: The downsides/upsides of the security according to the paper: It is argued that the code availability and ease of access can be as well a good or bad approach for security depending on the honesty and quality of the responsible ones. Nevertheless, it has been hard to define and formalize some flaw in making visible the issues to fix them rather than having the issues but hiding them.

The code availability might result in a more secure system since the vulnerabilities are exposed and they are easier to find and fix as soon as possible. One contradictory idea is that the users can find easily these vulnerabilities and use them against the system if the project is not updated at the time. Something similar happens to the peer reviews, it is argued that it will not be useful until someone with the proper level takes the time to assess it properly. But the perspective from the open source approach is that it will take time but it will for sure be assessed and this certainty is not achieved in closed source systems.

This research found that more metrics are needed as well as more specific studies regarding the security of open source systems: the different analysis is required since there is a possibility to use frameworks, peer-review methods or also a systematic review of the system. The user also needs to be taken into account since the users are the ones who benefit the most from the security of the system. All these characteristics are easily extrapolated to the open science world where more collaboration and better approaches are needed. The myths related to the open source systems can also be found in the open science world. There is a generalized idea that there aren't any breakthroughs without any monetary gain, its necessary to institutionalize the advantages of the opportunities of contributing to ones field o research.

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Appendix: Comparison Table

Title	Future Work	Conclusions	Publication Year	Open-Source software development process analysis	User Satisfaction	Cons for Security	Pros for Security
Adoption of open-source software versus proprietary software: An exploratory study. **Reference** **(**Dhir, S., & Dhir, S. (2017). Adoption of open-source software versus proprietary software: An exploratory study. Strategic Change, 26(4), 363–371. https://doi.org/10.1002/jsc.2137)	- The industry-specific analysis is missing for the analysis since there seems to be a lot of variations on it. - Why is there some missing free support for free OS when users are happy to pay huge amounts for the support in proprietary ones?	It uses specific-cases conclusions and comparisons where the highlighted results were for this industries: - Computer OS - Mobile OS - Web Browsers - Hypervisors and the general findings where that user like open source the most when they get the "free online support" and if the "commercial support" is needed, then the users tend to lean towards proprietary software	2017	Zachman framework and Checklan's (1981) CATWOE technique	100% of open-source users are satisfied with the security offered by their OS. For proprietary OS users, approximately 80% seem satisfied with the security features.	- Harder to find support in some cases depending on the project - A lot of lost projects by the original creator - Lack of motivation	- Successful cases like Mozilla that improves daily with user feedback - Peer Review has seen as something that helps improve the quality of code because everyone has the same goal for the project - User satisfaction as one of the driver
On the security of Open Source **Reference:** (Payne, C. (2002). On the security of open source software. Information Systems Journal, 12(1), 61–78. https://doi.org/10.1046/j.1365-2575.2002.00118.x)	-	- Harder to find bugs on the propietary source, and easier to find them in open source. - Peer review process is not particularly effective and many bugs will not actually be found. (Really hard to find the more subtle bugs in open source, even less likely to be found in the closed source). - Vulnerabilities are more likely to be found and fixed in open source software. It is less likely that the vulnerability will be found by an 'honest' user who merely stumbles across it if the code is not available. On the other hand,	2002	It divides each section of possible flaws in security and analyzes them based on what is done in them	It uses a subjective approach more based on the author's perspective of his experience	- Vulnerabilities are easier to find. - It depends on the goodwill and honesty of the users with the permissions	- Not every programmer who looks for the bugs is prepared enough to find them and fix them. - If you do not find the bugs, they do not exist. So the problem with open source

		malicious parties are much more inclined to closely examine and probe a piece of software specifically in order to discover a vulnerability. - Based on these results, it would appear that open source systems tend to be more secure.					is that these bugs will be easier to be found in comparison with a propietary source.
Is Open Source Security a Myth? **Reference** **(**Schryen, G. (2011). Is open source security a myth? Communications of the ACM, 54(5), 130. https://doi.org/10.1145/1941487.1941516)	- It is still challenging to retrieve consistent and comprehensive vulnerability data and patch data. New methods that collect automatic data, would be useful for future research.	- The type of software (Open Source and closed source) is not the primary driver for software security.	2001	- In debt studies comparing the security of open source and closed source software. Compared published vulnerabilities of 17 widely deployed open source and closed source software. - Comparing data related to the development of vulnerabilities disclosure over time, the severity of published vulnerabilities, and unpatched vulnerabilities and their severity	It uses an objective approach based on the analysis of data.	It is important to provide strong economic incentives for software producers to make software less vulnerable and to provide patches	OOS seems to prevent "extremely bad" patching behaviors
Does Open Source improve system security? **Reference** **(**Witten, B., Landwehr, C., & Caloyannides, M. (2001). Does open	- There is a need for developing metrics that can reflect security delivered to	- There is not a precise conclusion in which one of the two types of software (open source software and closed source software) is preferred although four conclusions were presented and three of them in favor of OOS.	2001	- Based on peer review - Analysis and comparison of data related to the period after a security flaw becomes known to	It uses a subjective approach more based on the author's perspectives	- Closed and proprietary system development models face disincentives toward fielding and supporting more	- Access to source code lets users improve system security - Open source life cycles produce systems

source improve system security? IEEE Software, 18(5), 57–61. https://doi.org/10.1109/52.951496)	the customer.			attackers and before the flaw is removed in Red Hat Linux (OOS) and Sun and Microsoft (CSS).		secure systems (as long as less secure systems are more profitable)"	that are less vulnerable to non-malicious faults. - The open source operating system experienced less exposure in the form of known but unpatched vulnerabilities (based on empirical support)
Why Open Source Software / Free Software (OSS/FS, FLOSS, or FOSS)? Look at the Numbers! **Reference** **(**Wheeler, D. A. (2007). Why open source software/free software (OSS/FS, FLOSS, or FOSS)? Look at the numbers. 514-520.)		- Most of the researches and publications conclude that OSS has security advantage over Proprietary Software, although is very hard to measure security in software due to the lack of standardized quantitative metrics. - Proprietary Software has increasingly include OOS components or modules into their design. That makes de security measurement even more difficult to perform.	2001	- Compiled a list of studies made by different researches about security and vulnerabilities in Linux and Microsoft Operation Systems. - Collect data from the studies and get quantitative metrics. - Compare the quantitative metrics obtained in order to measure security level between OSS and Proprietary Operation Systems.	It uses an objective approach based on the analysis of data.	- Some studies have argued that making the source code available gives attackers an advantage because they have more information to make an attack. - It is not guaranteed that contributors in OSS have the technical knowledge and capability to cover security concerns in the software, due to the fact that developers and reviewers are volunteers.	- In OSS the code is reviewed by a significantly large community, so it is easier to detect security issues, and also get them fixed faster.

Is there a common understanding of Open Science?

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Abstract. Thanks to the information technologies, Open Science, a knowledge sharing initiative, has experienced a relevant growth in the recent years. Different authors have analyzed this initiative from different perspectives but, is there a common understanding of Open Science? This paper tries to answer this question by analyzing a representative sample of publications on the matter, studying the different definitions taking into account the different points of view. The results show that there are discrepancies under all perspectives, even if they share the same basis. However, the realization of open science is mostly affected by the discrepancies on the legal and economic fields.

Keywords: Open Science, Open Access, Research, Disagreement, Openness, Reproducibility, Transparency

1 Introduction

Science is the study of the structure and behavior of the physical world, especially by watching, measuring, and doing experiments, and the development of theories to describe the results of these activities [1]. Scientists and researchers are focused on improving the knowledge of one specific topic; however, without previous knowledge this could not be possible. Every individual scientist can contribute with creativity and intuition, but for validating and confirming it is necessary collaboration and control of other specialists. So, development in science is the result of conclusions formulated and validated by the effort of a group instead of one individual. This idea comes from the 17th century when the collaboration between scientists was useful through scholarly publications, creating scientific societies that generate scientific journals dedicated to the diffusion of scientific research. Nonetheless, this knowledge diffusion was not always accepted in that way. Some researchers said that science is "uncooperative" and "self-serving". Moreover, this sharing could not be possible because of lack of availability of data, report of methodologies for reproducibility of experiments, among others. As a reaction, the Open Science (OS) movement was born [2].

OS takes into account some vital features of science: transparency, openness and reproducibility. However, these features are not applied as a daily practice, may be for a lack of encouragement of open practices from the academic system. For example, only are published results statistically significant, leading to a lack of knowledge.

Lots of individual researchers don't have many motivations to be more transparent although this would make science more credible. This fact is because a lack of centralized means and procedures to align common motivations. So, there is a lot of complexity in reach a greater openness because it may require the effort from all stakeholders. In order to drive researchers' behavior to be more open, it is necessary to follow a pathway executing specific actions [3].

The most widely used definition of OS was originated from Michael Nielsen: "Open science is the idea that scientific knowledge of all kinds should be openly shared as early as is practical in the discovery process". Doing that, the main aim of OS is to accelerate the scientific progress that could benefit everyone. In order to reach that, all scientific outputs should be available and easily accessible for others to use. Because of Internet, science is more open, global and collaborative than ever, and therefore OS is a very important topic. For that reason, OS wants to be followed by several institutions, but its definition and implementation are constantly shifting and evolving, leaving researchers in doubt about how to adopt OS and which are the best practices to follow [2]. Furthermore, there are some discrepancies across disciplines and there are some barriers that difficult the adoption of OS. This paper aims to analyze different definitions of OS and Open Access (OA), trying to find the common points and also the discrepancies from different authors. Doing that, it could be possible to know if OS is unified, meaning that similar pathways are followed to reach a common goal. This fact is important, in order to avoid wrong practices that may not comply with ethical, educational, legal, social and economic aspects.

OA is part of OS, referring to journal articles that are considered to be the current central communication process. There are several tools to build a better OA, mainly through Internet, for example ScienceOpen, Open Access Button, among others. Also, OA originates Open Data (OD) that consists on publishing supplementary files to the articles and deposition of data in repositories in order to re-use data to reproduce research results. These concepts are going to be used in our study, and it's interesting to know the impact to the web of them. In Figure 1, it can be observed the trends searched in Google [4], where a value of 100 means that there is maximum popularity, 50 half popularity and 0 that there is no enough data for this term. It can be observed, that around the year 2004 OA was so demanded, however this popularity decreased through the years. Nonetheless, the trend of OD and OS seems to be in increment every year, meaning that they are a remarkable topic to study.

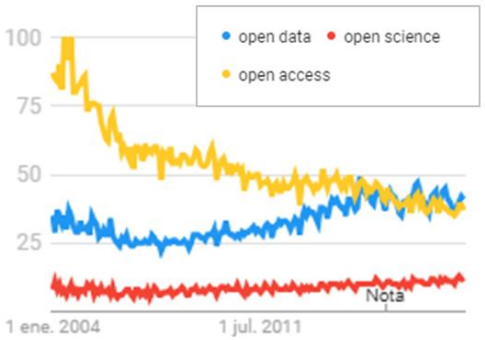

Figure 1. Google trends of OS, OA and OD on the internet [4].

2 Research methodology

The research methodology applied for this piece of research is similar to the steps in conducting a literature review defined in J.W. Creswell, 2003 [5]. The initial phase consisted of looking for some key words related to OS, as open science, open access, open data, etc. and searching for relevant papers on the matter. Given that starting set, it was expanded it iteratively by looking at the citations of those papers. After a few iterations, a good coverage on the matter of publications on Open Science is assumed.

The next step is summarizing and extracting relevant information from those papers, namely definitions, typologies and schemas regarding Open Science. This curation would allow to analyze and compare better the different visions on Open Science. It is desirable, as a byproduct of the analysis, to draw an analogy between Open Access and Open Science evolution and current situation. Given that OA initiatives are older and more mature now and tightly related to Open Science, a comparison would allow us to see if their common understanding issues are similar and if is feasible to extrapolate OA situation to OS.

The analysis was structured by dividing the results in different perspectives with the aim to show a clearer picture of it, in the same fashion of the five schools of thought proposed by Fetcher and Friesike [6]. For our analysis, five different points of view on OS are proposed: ethical, educational, legal, social and economic.

Due to time constraints, a truly thorough exploration of the different papers written in the matter is not possible. Probably, some relevant papers are missing, but more time would be needed to achieve a perfect coverage. Also, repeated reading of the publications would improve the extraction process.

As an extension to the methodology proposed, it would be interesting to interview and/or poll different populations (i. e. researchers vs. general population) in order to expand our investigation. This would bring a more updated picture into the mix, allowing us to compare it with the historical records that represent publication and maybe see better where the trend is going to.

3 Results and discussion

OA is a fundamental part of OS that refers in agreement of all authors to the free accessibility to scientific publications and scientific data. Open science is the term that refers not only to scientific publications or sharing data but also to all scientific knowledge.

But there are slightly differences between definitions that may influence in the complete achievement of OS and OD. In the case of OA for example, some authors focuses only to the free accessibility to scholarly research for scholarly journal articles [2] while others refers to the free access to articles for any users that need it [7].

All authors agree that OS is the idea of free accessibility to all kind of scientific knowledge in order to accelerate the scientific progress and increase efficacy, see

references [7], [8], [9], [10] and [11]. Some authors also refers to the idea of no copyrights [8] although it is not something that concern all authors.

Open science and, in consequence, Open Access can be defined, studied and evaluated from different points of view and even when analyzing the arguments from a same perspective there are discrepancies. Thus, according the proposed methodology, OS and OA are analyzed from the following perspectives: ethical, educational, legal, social and economic perspectives.

3.1. Ethical aspects

The ethical argument that is shown more clear in the definition is the fact that OS leads to a more scientific progress and a reduction in effort for the scientific community [12][13]. As stated in The European Code of Conduct for Research Integrity [14] one of the good research practices is that science has to be made of collaborative working. Also, there is the fact of reciprocity. The findings of research funded by the public should be made freely available to those who have paid for it [12][13].

Also subscription-based models of publishing are unfair and exploitative because they require publicly-funded academics to submit their work to commercially run journals, to carry out peer-review and sit as members of editorial boards, and then to pay to access the fruits of their own intellectual labor [12][13]. However, it has not to be taken for granted the idea that OS will generate science of better quality. Also, researchers less known in the scientific community have to have the same opportunities in platforms of OS [12].

For different reasons there are some controversies between those who focus in the ethical arguments to support or not OS. All authors make emphasis in the obligation of this reciprocity between researchers and users. But there is a concern about the quality of the OS that is published and shared. This controversy would slow down the development of OS.

Despite all of this, ethical arguments in favor of OS, specially the speed up of science development, are visible in almost all the definitions of OA and OS.

3.2. Educational aspects

The visibility of all research outputs is increased once they are open. This should lead to a citation advantage, as users who can easily download open versions of outputs will cite these versions as everyone with an Internet connection will have access [9]. Then, linking this field with the ethical one it represents a good way to make inexperienced researchers more known. The academic point of view is really linked to the democratic school of thought that states that any research product should be freely available. Everyone should have the equal right to access knowledge as it is a necessity for human development [6].

Among the authors that focus on this educational point of view there are no discrepancies, everyone should have access to knowledge by right. However, under other perspectives, some authors state that this knowledge should be free for students but not for everyone.

3.3. Legal aspects

The issue of the ownership of rights is particularly important in the context of public-private partnerships because it can greatly influence the manner in which research output will be disseminated. The private party will typically attempt to protect their commercial interests. This means that, depending on the option chosen, some restrictions may be placed on the distribution and reuse of the publications and data, for example by limiting commercial reuse [7].

Although the possibility exists to restrict use for commercial purposes, the distinction between commercial and non-commercial use raises questions not only in the scientific publishing sector, but also in several other sectors of the copyright industry, as it may leave too much room for interpretation [7].

There are no apparent barriers for OS when the research is publicly funded but some problems arises when the research is not totally public. Then, the ownership of rights moves us away from the most altruistic spirit of the definition of OS and also OA.

3.4. Social aspects

The majority of scientists and the whole society consider transparency, openness and reproducibility (main characteristics of OS) as essential features of science but they are not reflected on daily practice [3]. Although sometimes the technological progress is limited by the assimilation capability of the society, in the case of OS, the society is apparently ready but other points are making difficult the application of this idea. Moreover, the openness of science is something that is getting more and more feasible, motivated by the general thought that the access to the knowledge should be a right. In fact, access to knowledge was recognized as a human right in Article 27 of United Nations Declaration of Human Rights.

On the other hand, scientific literature is not only useful for academics and researchers but also for all the society. A clear example is the situation of a patient that has been diagnosed from some disease and may like to read scientific papers about his or her concern to be aware about the situation. Also, there are cases of extreme public interest in science as epidemics, astronomic catastrophes, etc., that closed access would only impede. Then, according to the different definitions, OS will help to transmit knowledge and improve human being and in extreme cases like epidemics, prevent deaths.

OA allows people from all over the world to equally access to information. Due to the high prices of journal subscriptions, developing countries struggle with access just as in developed countries. OA provides a mechanism to level the playing field between developed and developing countries. The pay-to-publish system also is a potentially greater burden for authors in developing countries [15].

In conclusion, science is not only for scientists or professionals, in the society people are ready for having access to scientific knowledge and they are concerned about the respect of their rights. Anybody has the needed tools to access to the knowledge; the only current barrier is that it is not broadly open.

3.5. Economic aspects

Considering that a huge amount of scientific research is funded by external money and the knowledge has been considered as an economic good, what will happen in the market if the OS is instituted? It should be considered that the current structure of research process is the result of years of evolution and a sudden change could produce unexpected consequences.

Inside this structure, not only do publishers maintain the information technology infrastructure that support and control access to content and create new one, but also they perform other important functions as organizing the peer review process, developing and implementing policies (as responsible conduct of research), addressing authorship problems, other technical tasks and managing relations with authors, vendors and the media [11]. All this work should be rewarded somehow and that seems the main economic problem of OS.

Also, recent studies [16] showed that the five more prolific publishers, including Reed-Elsevier, Taylor & Francis, Wiley-Blackwell, Springer and Sage, control over one-half of all the scientific journal market and their profit margins are in the range of 25 to 40 percent. Consequently, this leads to a lack of competitive pressure in this industry, avoiding a change in the way they operate, for instance to the OS.

Unlike other property-based businesses like recorded music, these scientific publishers have been able to adopt new technologies while they maintained a business model based on subscription revenue. In music, firms pay creators for content and in research creators pay firms [11].

Fortunately, OS is present, but it did not seriously affect the market share of commercial and non-profit publishers of high-prestige journals. The main cause is that stakeholders do not want to change the model and also they not have arguments for doing it [11]. Researchers have no market power and they prefer to publish in a widely read journal; universities seek to maximize the visibility of their research and research funders use journal publications as proof of quality (the peer review is designed to find the best science to fund).

OA business model shifts the costs from subscribers onto the researchers. And they are not always able to pay them. In conclusion, the whole model should suffer changes (fundamentally the measurement of research quality based on the name of the journal and funding methods) to reach the OS. The whole access to the scientific knowledge does not should be only to the articles that voluntarily decided to be public, but people also should have access to high-quality publications.

4 Conclusions

Following the proposed methodology, it has been tried to search the common points and discrepancies of the different definitions of OS and OA. In order to face it in a clearer way, different perspectives have been analyzed for organizing the ideas. Actually, it is shown that there is a common understanding of what OS and OA are. Nevertheless, the discrepancies between authors in the definition itself and the legal

framework that regulates the intellectual property make difficult the efficacy in practice.

The methodology has focused on finding the comprehension of OS from different points of view. The different opinions of each of the authors analyzed influence the perspective of the subject under study. However, as the analysis has been performed using academic papers, the results should be interpreted considering this context. In other words, it may not represent properly the thoughts of the whole society.

The main worry from the ethical perspective is that free access to information could incite the distrust in the quality and reliability of information. Besides, it could be thought that even the more inexperienced sources don't provide accurate information. However, it has been found an agreement regarding to the reciprocity need between researcher and society. From the educational orientation, there are no discrepancies about the belief that knowledge has to be open to all the society. Nonetheless, other authors out of the analysis from this educational perspective differ because they think that the access must be restricted to the student community. Nowadays, with the aim of carrying out the publication of the knowledge, some legal procedures have to be fulfilled. Moreover, the current law about the intellectual property suppose an obstacle to get the goal under discussion. Regarding the social implications it is not being taken into account the knowledge as something uniquely informative outside the scientific community. Also, the OS promotes the equality of opportunities for the whole society. Respect to the economical view, the traditional research system does not show any incentives to go to an open model due to, above other things, the oligopoly of the research industry and the low power of change of researchers and the society. Among all the analyzed perspectives it was taken out that the main barriers for OS and OA are the legal and economic ones, due to the fact that they are two giants that neither the society nor the researchers can manage directly.

Within the different assessment perspectives, it has been found a convergence regarding the right of access to information from a more technical and scientific point of view inside the society, making available primary sources. It has been concluded that there is an understanding with regard to the definition of OS and OA.

As a future work remains the analogy between OS and OA proposed in the methodology and the addition of interviews/polls to the study. Both tasks were beyond the time constraints imposed by the format of our research but probably would add interesting nuances to the results of this paper.

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An Examination of the Use of Barcelona's Open Data within Academic Research

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Abstract. The aim of this research is to better understand how the open data, published as part of Barcelona's smart city initiative, is used within academic research. Using data found by searching for references to Barcelona's open data in Google Scholar, 27 articles were analyzed with respect to the content of the article including subject matter and keywords and also analysed with respect to a number of meta-data characteristics including year of publication, and institution type. The general findings in this paper is that there are very few papers which actually use the data, most merely reference Open Data BCN as part of their discussion. In general the focus of the papers was in two areas: business aspects of open data and on building software tools to assist with interaction with the data. The majority of the research originates from either business or computing departments of universities.

Keywords: open data · smart cities· Barcelona · open science

1 Introduction

1.1 Barcelona's Open Data and Smart City initiative

Good quality academic research can play an important role in shaping the future of a society. This is especially true if the research is about the data generated by the society itself. The city of Barcelona is one of the frontrunners in the process to become a smart city. It has been ranked 1st in 2015 and currently ranked 9th globally in the world by Juniper Research [1]. As part of the smart city project, many successful projects have been implemented in sectors like public transport, governance and urban infrastructure [2]. To make the 'smart city' project successful, Barcelona is heavily adopting community driven initiatives which are often aided by open science approaches. The concept of open data which is a subset of the broader open science idea has materialized into the 'Open Data BCN'[3]. 'Open Data' or 'Public Sector Information Openness' is a movement driven by public administrations with the main objective of maximize available public resources, exposing the information generated or guarded by public

bodies, allowing its access and use for the common good and for the benefit of anyone and any entity interested. Open Data BCN, a project that was born in 2010, hosts a large and regularly updated database on the themes of: Administration, Economy and Business, Population, Territory, and Urban Environment. By enabling access to the public data and adopting open governance policies, the Barcelona model is transforming the data providers to decision makers. [4]

1.2 Motivation

In the research community, a common difficulty is to find reliable and accurate data. The authors feel that the Barcelona Open Data can be put to use in the academic research context to gain a lot of insights about the people, environment and systems in the city. To find out how this data is being used in research, we decided to do a systematic review of the academic literature available in the Google Scholar corpus. It is important to know whether the data is being used in the ways we think it can be used, who is using the data, what kind of problems are they trying to solve, and is the true potential of the available data being fully tapped by the research community. By finding the trends in the usage of this data we can possibly learn more about which data sets are being utilized the most. A further investigation can be carried out to make the data more easily accessible to retrieve and use.

2 Research Methodology

The research focuses on usage of data made available by Open Data Barcelona which is data service of the Barcelona City Council. Our aim was to gather information related to the use of data by different organisations and institutions.

We conducted our literature search by looking for the exact phrase "Open Data BCN" on websites containing or linking to academic research papers. These websites were arxiv (https://arxiv.org/), Mendeley (www.mendeley.com) , and Google Scholar (scholar.google.es). The reason we chose to search the exact phrase stated above is that, on the Barcelona open data website, it specifically requested that data be referenced using one quote for webpages and a slightly different one for text, Open Data BCN was included in both approaches so it allowed searching both potential types of information simultaneously. Of the three research paper websites we initially selected, our search approach did not give results on arxiv or Mendeley so we decided to use Google Scholar as our sole resource. It should be noted here however that one of the research papers found through Google Scholar was in fact hosted on arxiv.

The search for papers was conducted on 2nd of November 2018 and initially provided 59 results. After a preliminary investigation it was found that 30 of these were in a language other than English. Of the remaining 29, one was a dead link and two links were pointing to the same result. The data set was pruned to contain only the 27 working, non-duplicate links in English language.[A] The reason for excluding non English language results was one of pragmatism in

that it is the one language all researchers are fluent. Equally it avoids bias in the qualitative results (which is discussed further below) essentially if a single researcher analysed all of one particular language it would not be known if potential similarities are due to the language or the researchers understanding of the text (independent of language).

The approach to analyse the data set was to divide the data set equally between the researchers so that each researcher analysed approximately 25% of the data set. To maintain uniformity in the analysis of different researchers, it was decided to split the analysis into two sections: quantitative, and qualitative. For the quantitative approach different aspects of the metadata of the research was assessed including date, type of institution, country of origin, which specific data sets were used in their analysis, and in what type of publication the paper was published . For the qualitative approach the content of the papers and the keywords were assessed and categorised by the researcher into groups denoting the focus of the research.

Before presenting our results we will discuss some of the strengths and weaknesses in our methodology. The strengths of our approach is that it is easily understood and can easily be repeated by others to confirm results. Also it can be scales up to larger bodies of research with the inclusion of more researchers.

The first potential issue with the methodology is the assumption that papers that used open data from Barcelona correctly referenced their use of the data. Any incorrectly referenced uses of the data are unlikely to be uncovered following our methodology. Secondly, the use of only one source (Google Scholar) to find the data potentially biases the methodology towards Googles search algorithm/coverage. Finally, our division of work between different members of the research team may lead to potential differences in the researchers opinion/understanding of the material when qualitatively analysing the data. Some ideas for improvement of research methodology can be found in the future work section below.

3 Results

The first thing to note is that 6 (22%) of the data set was not accessible due to the referenced research papers being behind a paywall and there was no budget within this work to buy access. However, we were still able to produce some statistics from the metadata and abstracts as that was accessible to us. However it was not possible to ascertain what if any data sets they use.

Although here we refer to our data set as academic research and treat all data as equally valid and weighted, the researchers are of the opinion that some of the literature appeared to be business papers or presentations and not research papers. The Open Data BCN statistics page [5] shows the absolute number of downloads for the top 5 data sets since 23/2/2017 totals over 1.2 million, whereas only 59 articles were found (with the 27 which were investigated here being the articles written in English).

3.1 Quantitative Results

The approach taken to produce the Figure 1 was to count the number of unique institutions mentioned in all papers. If a paper has researchers from three different universities each unique university is counted, hence why there are more universities than papers.

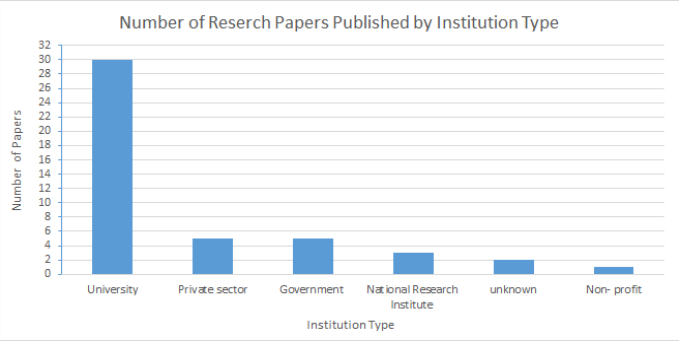

Fig. 1. Number of papers by institution type

As seen from Figure 1, the majority of the research has been conducted by universities. This is to be expected as they are the institution which focuses highly on producing academic research papers. With the exception of Universitat Politecnica de Catalunya (UPC), every institution found was only involved in one research paper. UPC was involved in the creation of six papers from the data set, UPC being situated in Barcelona is expected to be more aware and involved in the projects involving to Barcelona Open Data.

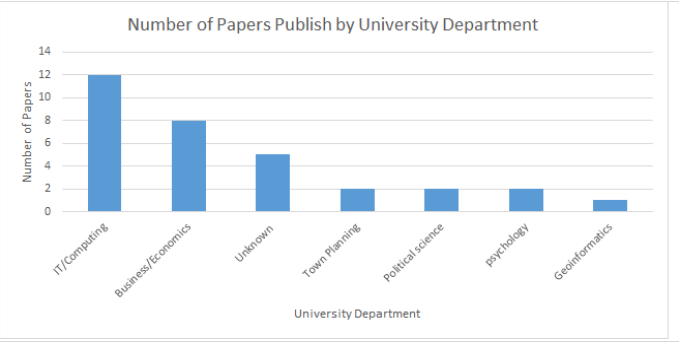

Fig. 2. Number of papers by university department

Majority of the publications come from IT/Computing and Business/ Economics departments. The next largest university department is the group which the researchers could not discern mostly due to lack of available information in the metadata and an inability to access the actual content of the paper. It was an expectation of the researchers that IT/computing departments would be large consumers of this type of data. The use of the data within business department was not something that was initially expected and possibly is a reflection of the increasing need for digital and data skills within general business.

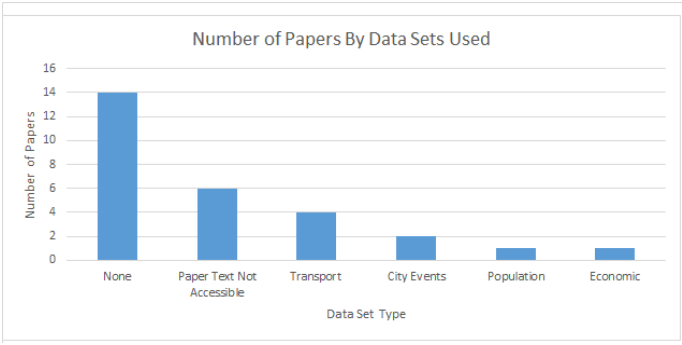

Fig. 3. Number of papers by data set used

As Figure 3 shows, very few of the papers which cite Open Data BCN actually use a data set. Many appear to reference Barcelona as a smart city for use in a general discussion. Of the data sets that are being used for academic research transport is the most popular. Possibly this could bring into question the quality of other data sets in the open data portal. This has not been investigated in this research.

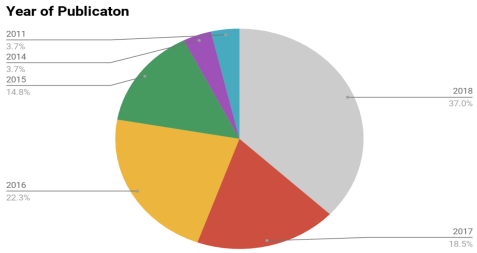

Fig. 4. Proportion of data set by year published

Figure 4 shows that from a slow start the pace of use of the data is generally increasing over time. It should be noted that the research has been conducted in November of 2018 and as such the final number papers published in 2018 could increase. Also that online data portal opened in 2011 possibly giving some explanation as to the relatively few papers published in the initial years.

3.2 Qualitative Results

In figure 5 we are analysing the categories into which the keywords can be grouped.

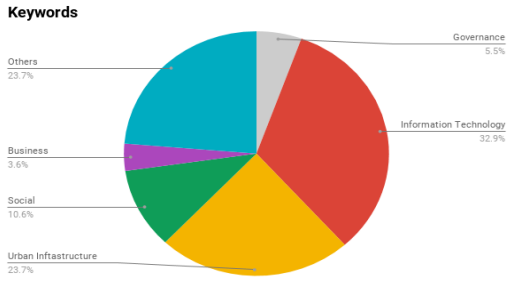

Fig. 5. Categories of keywords

Note this is qualitative as it is the opinion of the researchers as to which words falls into which category. From this we can see the main focus of the data set is information technology. Although the original major topic of business/economics which was suggested by the initial analysis of the university departments here shows there is a natural splitting of this into more granular categories Business, Governance, Urban Infrastructure. It should be noted here that the distribution of keywords among the data set was not uniform. Thus papers with more keywords will have a higher weighting with respect to this analysis. Also some journals noted that their keywords were picked out by algorithms which could bias results as these words may not have been what the author would have wanted.

Here we include some general points after reading all the documents which have not been captured above. Again this section is highly subjective and is entirely based on the ideas of the researchers. For this reason this section has been kept in the format of general points in written prose. Improvements to this approach have been suggested in the future work section below. In general most papers only use Open Data BCN as part of their general discussion into smart cities, as a specific case study for comparison, or to discuss business frameworks which involve data. In many Barcelona plays a very small role in the discussions

so could be argued that these could be removed from the analysis as it is not a major focus of the research. Many of the articles did not seem like academic research. Some appeared to more closely mirror business marketing thinly veiled as research, or were PowerPoint presentations (although they were included to keep with the research methodology). Of the ones that utilised the data the main focus was generally not Barcelona, the open data provided by Barcelona was merely a means to their research (either on APIs, or visualisation, or data to test a model) rather than an end. There are however a small minority of papers whose research could claim to focus on improving the city these tend to focus on more local issues such as noise and improving, or improving access to information on, transport.

4 Conclusions

Our findings are that Barcelonas open data is not used significantly in academic research. This is shown by the almost negligible number of research papers found with respect to the number of reported downloads of data from Barcelona's open data site. It is also shown by the fact that only a minority of the papers analysed actually use data, many merely use Barcelona in their discussions as an example of a smart city. In addition to this it was also found that transport, city events, population, and economic data were the only data sets actually used in academic research. As can be seen from the years of publication the general trend is increasingly more papers are being publish over time. Thus, although there is minimal use of Barcelona's open data currently in use in academic research, this conclusion may change in the coming years. In addition to the above it was also found that the research is mostly being conducted by business/economics departments, and ICT/computing departments of universities. The final finding of merit is that, although there was a small minority of papers which used the data in a way which could be argued is to the benefit of Barcelona and its citizens, the main use of the data was in improving software systems which interact with (Building of APIs) and display (building of data visualisation tools) data in general with no specific focus on Barcelona.

5 Future Work

Due to a limited time-frame available for this research, we are aware that there can be a significant improvement in this work especially regarding some assumptions and the methodology. Hence the possible improvement and augmentation strategies for the above issues will be briefly discussed. A research team with sufficient language ability could complete a full analysis of the results returned by Google Scholar. In order to improve the approach with respect to all the issues outlined in the methodology section above the researchers believe a more technical approach could be taken to data collection and analysis. The use of Application Program Interfaces (APIs) would allow for programmatic access and analysis of the data. Programmatic access would allow for more complex lists

of search terms (including combinations of other keywords, synonyms, and wild cards) which would be laborious for a human researcher to run. These would allow us to find uses of the data which were not referenced specifically as requested by Barcelona's open data website. To attempt to be more rigorous in our analysis of the text of papers within the data set text analysis techniques could be applied across the corpus of data. This would ensure that all papers are analysed in the same way giving more consistency in the analysis. Examples of text analysis techniques which could be applied are entity extraction to extract and categorise the open data BCN data resources used in the work, and topic modelling to understand the topics of the papers which use the open BCN data. A potentially better (albeit more technically challenging) solution would be to cast a wider net to find more uses of the open BCN data would be to build a general web scraping tool to search the wider internet for mentions of the open data provided by Barcelona. Due to the challenges around access to some of the papers in order to take this work further it would be advisable to have a budget to grant access to papers which are unavailable to students at Universitat Pompeu Fabra. Finally the researchers suggest conducting this analysis again in 2019 to investigate whether the temporal trends uncovered continue into the future.

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A Appendix: Data set

To access the data set used for the analysis follow the link below:
https://drive.google.com/a/estudiant.upf.edu/file/d/1oofIVd69Da64rMqN-UdFjq79407UGHua/view?usp=sharing

Impact of ethical frameworks in healthcare-AI development

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Abstract. Artificial Intelligence (AI) has been extensively applied to healthcare-related technologies. Lately, it has also given birth to novel ethical issues and the development of these technologies nowadays coexists with different ethical frameworks that change depending on the country and whose effects are yet uncertain. In the present paper we try to measure the impact of these frameworks on the development of healthcare-AI, comparing the trend of the number of publications with other AI fields that are free of ethical issues. We use different databases to measure the trends of publication before and after the rise of papers related to ethical issues, and we additionally segregate the results by country. Results show that there is no correlation between different legislations and the number of research papers published, as well as not apparent correlation between the number of publications regarding ethical-AI and healthcare-AI.

Keywords: artificial intelligence, AI, healthcare, ethics, machine learning

1 Introduction

Artificial Intelligence (AI) unlocks enormously beneficial innovations in the field of healthcare. Personalized and precision medicine, more accurate and faster diagnostics, and accessible health apps boost access to quality medical care for millions. Chatbots offer 24/7 free therapy, wearables monitor biometric data in real time, and robotic devices improve surgical outcomes. Leveraging data from doctors' visits, digital devices and wearables, AI systems are able to consider unique patient history, genetics, lifestyle, diet, environment, and even bacterial composition of the gut [1]. AI is adding great value to the clinical process by taking over a big chunk of clinical and outpatient services, leaving physicians free to focus on more critical activities. For instance, machine learning algorithms are processing and analysing enormous quantities of information in the form of clinical notes, diagnostic images

and health records to quickly detect patterns and insights that would have taken decades before.

Timely, accurate detection has a huge bearing on treatment outcomes in the case of rare or difficult to diagnose illnesses. Unfortunately, medical practitioners can only analyse a limited number of images and samples, and their diagnoses are subject to human error. AI, on the other hand, can process millions of samples in quick time, consistently and reliably, every time.

Health Cyber-Physical Systems (HCPS) [2] is an example of this massive data processing. With sensors and systems, different medical devices cooperate to recognize the patient's physical condition continuously, particularly for basic patients. This remote monitoring is carried out thanks to new structures of perception associated with internet, which allows the collaboration between reality and representation. On the other hand, an example of machine learning in diagnosis is Morpheo, an AI platform that studies sleep disorders. To analyse sleep patterns is a time consuming, complicated exercise that is hugely benefiting from AI-led automation. Besides making it easier for physicians to treat patients, the platform is expected to yield predictive/preventive treatments in the future. AI is also holding out the hope of detecting diseases even before the symptoms manifest. A start-up in California has come up with an Adaptive Genomics Engine that spots disease signatures in the blood dynamically. It does this based on freely floating and dynamically changing genetic material, which offers a genomic picture of an individual at any given time[3]. In oncology, Somashekhar et al. demonstrated that the IBM Watson, an AI developed by IBM, would be a reliable system for assisting the diagnosis of cancer through a double-blinded validation study [4]. In psychology, a predictive model of schizophrenia has been constructed that, by means of deep learning using functional magnetic resonance images, a 74% identification of patients is achieved [5] and a deep-learning algorithm used MRI of the brain of individuals 6 to 12 months old to predict the diagnosis of autism in individual high-risk children at 24 months, with a positive predictive value of 81% [6]. Even in ophthalmology, an algorithm has been developed, identified with an algorithm of background photographs of diabetic patients and identifiers, with high reliability (94% and 98% sensitivity and specificity), to determine the cases that should refer to ophthalmologist for further evaluation [7]. The evidence is that AI applications in healthcare has arrived to all its fields.

This rise of AI ‘Healthtech’ is enabled by developments in machine learning algorithms, proliferation of digital and biometric data captured by digital devices, accelerating computing power, and advances in biological and medical sciences including in genomic sequencing.

However, AI brings new policy and ethical dilemmas. The potential applications of AI in healthcare are being explored through a number of promising initiatives across different sectors – by industry, health sector organisations and through government investment. While their aims and interests may vary, there are some common ethical issues that arise from their work. Stakes are high and human health and lives are at risk. Thus, there are some important questions that we have to consider: how to support beneficial innovation while minimizing human risks? Which are their limitations? Who is responsible for the decisions made by AI systems? Will increasing use of AI lead to a loss of human contact in care? What happens if AI

systems are hacked? What if different treatment decisions about patients are made depending on insurance status or their ability to pay? [8] An important issue is that guiding systems may be programmed to improve quality metrics but not necessarily patient care or maybe the underlying data used to train an algorithm can be incomplete or biased, and the functioning algorithm may then reflect these biases. *Danton Char*, [9], MD, assistant professor of anaesthesiology, perioperative and pain medicine, said that "*The one thing people can do that machines can't do is step aside from our ideas and evaluate them critically"*.

Besides, in [10] Cios et al. present an overview on the ethical frameworks. What follows is a summary of the key points of that framework.

- **Data ownership:** Ownership of patient data that is generated in a massive way is still an unsolved question
- **Fear of lawsuits:** There is a widespread practice among health personnel, especially doctors, which implies the reluctance to provide patient data, not only to avoid future legal action, but to cover up anomalies that could trigger unwanted investigations.
- **Privacy and security of human data:** The data obtained can be classified in the following categories:
  - De-identified data
  - Identified data
  - Anonymized data
  - Anonymous data

Governments and health systems must take into account the encryption of data, and thus avoid that their use for different purposes for which they were consented.

- **Expected benefits:** In order to use patient data, it must be justified, in an ethical and legal manner, that this use has a real benefit and should not be used for frivolous or unnecessary purposes.
- **Administrative issues:** There are administrative limitations that prevent certain data from being combined, since such a combination could change the classification category, that is, it could make the data 'identifiable'.

In this paper, we made a research about whether or not this ethical issues have influenced the development of the artificial intelligence and its applications in the medical field.

2 Research methodology

In order to evaluate how ethical frameworks affect the application of artificial intelligence in the field of healthcare, analysis of scientific articles have been carried out. This was evaluated by the analysis of the publication trends along recent timeline. In order to have a representative result analysis, another sampling was carried out in a field that was not subject to ethical limitations. In this case, the set of data that we will use for the comparison is that of artificial intelligence applied to the development of Natural Language Processing (NLP). We have chosen NLP as a

control group because the data necessary for training the machines is by far less sensible than using patient's pathology records. On the other hand, a temporary study was also carried out on the amount of papers published in relation to ethical aspects of artificial intelligence, to check if the peaks of publications and research on this topic had influence on AI research in medicine.

We have chosen the most widely used meta-research database and the most popular medical repository to search for articles, and in this way, the different tools that each one proposes for the search analysis can be exploited.

- **Scopus** is a multidisciplinary database of bibliographic references and citations that allows, through analysis tools (Citations search, indicators to evaluate researchers and indicators to evaluate journals), to know the qualities and impact of the literature consulted [11]. In Table [1] we show the keywords that were introduced in different search fields at the same search. Results were extracted in line charts.
    - Documents in relation to the geographical area.
    - Documents from a chronological perspective.
- **Pubmed** is a source of biomedical articles, whose geographical range is limited to the United States and the UK. This search is less specific, since in this case it cannot be hierarchize the search based on the keywords. For this, the key words 'artificial intelligence' and 'machine learning' were introduced in the fields of search for title and abstract. From this procedure the representation in bar graph of the number of publications from a chronological perspective was obtained.

Table 1 Keyword combination in Scopus search.

Keyword 1	Keyword 2	Number of papers
Artificial Intelligence	Medical ethics	113
	Medicine	3519
	NLP	6004
	Speech	5725
	Video	6720

As limitations of this methodology, we could highlight the use of papers on ethics as a marker of influence in the field of AI research in medicine. For a more accurate analysis could have been used legislation on AI, which is what ultimately limits the coverage of the research.

3 Results

Next we present the results regarding the trend of publication. In Figure [1] we show the data gathered from PubMed, where on the one hand we observe that proliferation of articles in the field of computational medicine has emerged since the advent of artificial intelligence and machine learning techniques. On the other hand, ethical-AI publications follows a more irregular distribution totally uncorrelated with

the healthcare-AI rate of publication. A decrease of the 50% on the rate of ethical-AI publications does not have any impact on the amount of research being done (see year 2016).

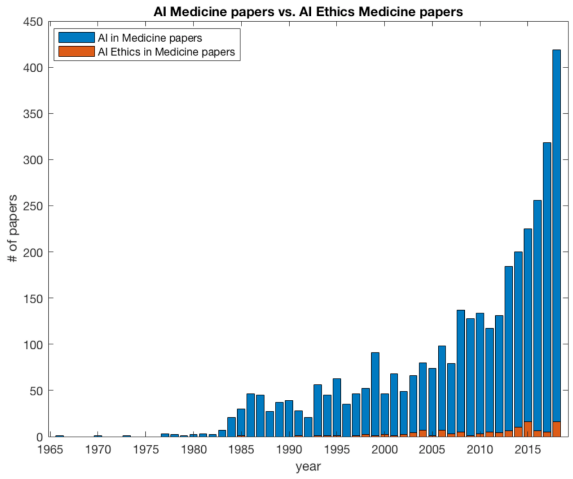

Figure 1. Number of publications in PubMed regarding the fields of healthcare-AI and ethical issues.

Besides, in Figure [2] we additionally present the same metric but in the field of Natural Language Processing. In this case we observe a larger volume of publications, with a pronounced increase since 2008 but following a more irregular pattern than in healthcare-AI.

In Figure [3] we address whether this trend is global or more pronounced in certain countries. We attach the results of the by-country number of publications in the Scopus database containing the keywords 'AI' and 'Medicine' in Figure [3a], and adding the keyword 'Ethics' in Figure [3b].

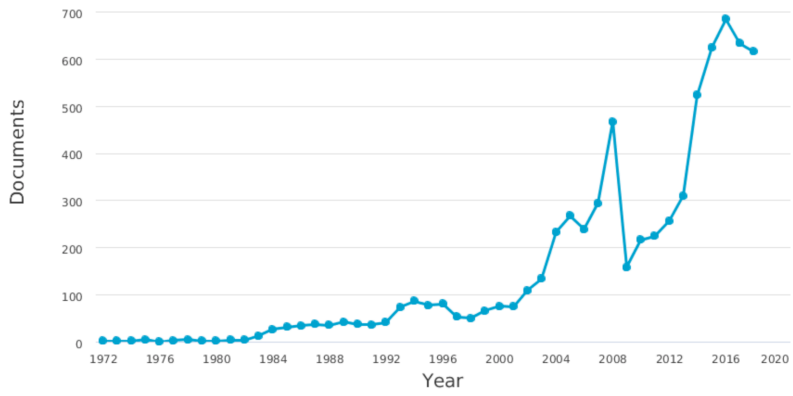

Figure 2. Published papers using the keywords AI and NLP, by year. (Source: Scopus)

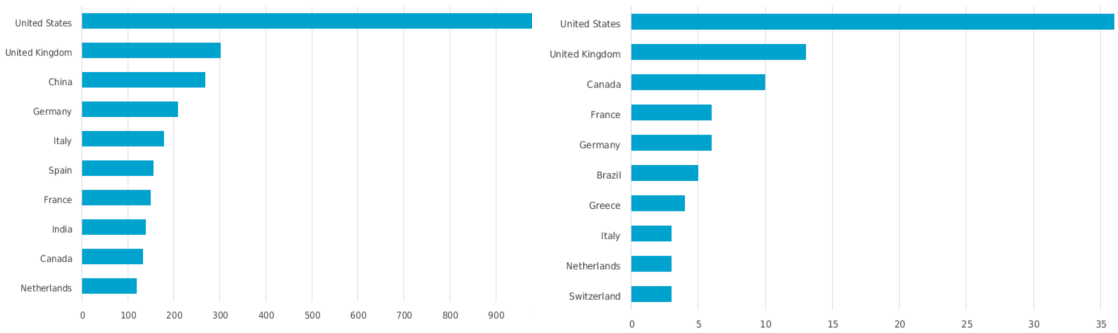

Figure 3. By-country publications using the keywords AI and medicine (left), adding 'ethics' (right).

4 Conclusions

We have shown different examples of healthcare-AI along with an overview of the ethical issues implicit to the field. Analysing our results should allow one to address if there is correlation between the amount of research and the awareness of this ethical issues.

On the one hand, it is interesting to see that China, despite being the third country with more papers in the fields of AI and medicine, is not even on the list of countries with more publications that covers some ethical aspect. The same happens with Spain, which does not appear on the ethical ranking despite being the sixth country in the world in healthcare-AI publications. Together with India, those are the only democratic countries present in the healthcare-AI top ten and absent from the ethical-AI ranking.

On the other hand, regarding the country-wise ethical frameworks, we observe that United States and United Kingdom have the most publications in English language, independently of the keywords used to query the results. This apparently implies that strong ethical frameworks (as the rate of ethical-related publication suggests) do not affect the amount of research carried out.

Besides, given that regarding the trends of publication we also do not observe any correlation between the amount of ethical publications and the volume of the research, we can conclude that ethical frameworks do not constrain healthcare-AI research in terms of volume, suggesting that researchers effectively circumvent this issues. The awareness of ethical frameworks (and therefore the appliance of more restrictive research rules) does not constrain the amount of research and, therefore, strong ethical frameworks are preferable.

Finally, we would like to point out that possible future work could include adding characteristics of local legislation on data management to our results.

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The inner workings of social media - manipulation and exploitation of our sentiment

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Abstract. Advancements in algorithms, analytics, and big data mining combined with the continued use of social media and social networking services as a source of communication, news and entertainment has provided social media corporations with access to unprecedented amounts of our personal information. This data which comprises of physical, emotional and sentimental information is often willingly provided albeit with a lack of active consideration as to whether or how it may be used, either now or in the future. In this paper we examine how and why social media and social networking corporations extract, store and analyse our personal, sentimental and emotional data, whether this may impact how we consume information, form opinions and interact with the world, and what awareness we really have in terms of unintentionally providing ammunition for possible manipulation. From providing advertisers with access to our emotions to facilitating the creation of the "echo chamber" [1].

Keywords: Social media, awareness, consumer manipulation, sentiment analysis, echo chamber.

1 Introduction

Social media and social networking services play an important part in society, providing the means and potential to share information with a broad audience. Services such as Facebook,

Twitter, LinkedIn, Instagram and similar provide the interface for users to post videos, comments, messages and info-graphics with the hope of interacting with on-line friends and followers. Engagement and conversation between groups of people who have similar personal or career interests is at the core of social networking[2]. Users build vast social relationships typically with other users who share common interests or backgrounds.
Users post comments, moods, videos, images and multimedia relating to their daily lives providing rich content concerning their relationship with the world and oftentimes containing sensitive or personal information[3]. However, what the Social media and social networking services primarily care about are two points: engagement and advertising [4].
Users are providing huge amounts of personal information which can ultimately be mined for the purpose of profit. In this paper, we will attempt to examine this topic by answering the following questions:

1. How do Social networking services companies exploit consumer information?
2. Why do Social networking services companies exploit it?
3. Are consumers aware of personal information exploitation and to what extend?
4. What are the effect of the above?

We seek to answer these questions and relate them to consumer awareness of sentiment analysis and the echo chamber effect.*"Social scientists are studying this echo chamber by applying computational methods to the traces people leave on Facebook, Twitter and other such outlets. Through this work, they have established that users happily embrace false information as long as it reinforces their preexisting beliefs."* [7] We will do so by conducting a survey and analysing the results.

1.1 How

Social media and social networking services, through advancements in algorithms and powerful analytic tools have unprecedented access to user information and user behaviour. There is an existing awareness that we are sharing profile information such as our religious views, political views, who you are "interested in," and so on based on the social media profiles should we choose to in addition to the more obvious information such as who we follow, who we unfollow, our likes or dislikes, the places we visit and so on however there are many metrics that are being gathered which we may not be consciously or acutely aware of, for example the Facebook data policy states, in the section relation to data sharing that *"this can also include what you see through features we provide, such as our camera"*. [14].

Sentiment analysis and data mining algorithms also have the potential to detect when we feel "stressed", "defeated", "overwhelmed", "anxious", "nervous", "stupid", "silly", "useless" or any other of an array of emotions. *"Sentiment analysis refers to the application of natural language processing, computational linguistics and text analytics to identify and extract subjective information in source materials."* [8]. We share all of these emotions via indicators which we provide through comments on our own posts or on the posts of others, or through comments made on our posts by others. We may be performing multiple interactions on any given day which we are

not consciously aware are giving access to our emotional state. All of this information can be extracted and analysed via the means of natural language processing, computational linguistics and text analysis. Facebook has received criticism in the past for experimenting on over 700'000 users news feeds without user consent and with the purpose of investigating if this manipulation would affect user emotions [7]. This alone indicates that the sentimental analysis capabilities are already in place Social media has the power to change our mood which indicates that it has the power to detect and measure our mood.

Many social media providers give users the ability to "like' or 'love' content and comments, this has been extended for example on Facebook to incorporate a wide set of 'reactions', including "Love", "Haha", "Wow", "Sad", or "Angry". As users we understand that we are providing this information for public consumption but are we really aware of its potential uses either now or in the future.

Another set of metrics which Social media and social networking services gather relates to the actual physical device attributes, Facebook is again the example we will use, they inform us on their privacy policy that they obtain information such as *"the operating system, hardware and software versions, battery level, signal strength, available storage space, browser type, app and file names and types, and plugins"*,[14]. in addition to device operations such as *"information about operations and behaviours performed on the device, such as whether a window is foregrounded or backgrounded, or mouse movements"*[14]. All of this information has the potential to be used to profile and categorise users in addition there is no "opt-out" for much of this analysis

1.2 Why

The primary objective of social media corporations, like every other corporation, is to make a profit. The use of these platforms is primarily free of charge, the customers, from an economic perspective are actually the marketing and advertising companies to whom the social media platforms is selling an advertising asset. The asset in question is the attention of the social media user, which means that the user is in fact the product. Algorithms using the data discussed above, are designed to show users what the algorithm determines they want to see with the primary objective of keeping users engaged, and entertained, because engagement increases attention, increases profit. Social media providers are selling marketing and advertising companies access to user attention, to space on the users news feed and perhaps even to the users emotions. In order to do this they need to retain user engagement by profiling users to ensure they are providing feed that will capture interest and increase engagement. As per Figure 1 and 2 social media platforms benefit hugely from this strategy.

Social media has the power to change our mood which indicates that it has the power to detect or mood, measure our mood and potentially use our mood against us. This can extend to providing advertising and marketing agencies not only access to obvious attributes such as location, likes and dislikes but also to algorithmic interpretation of user emotions .

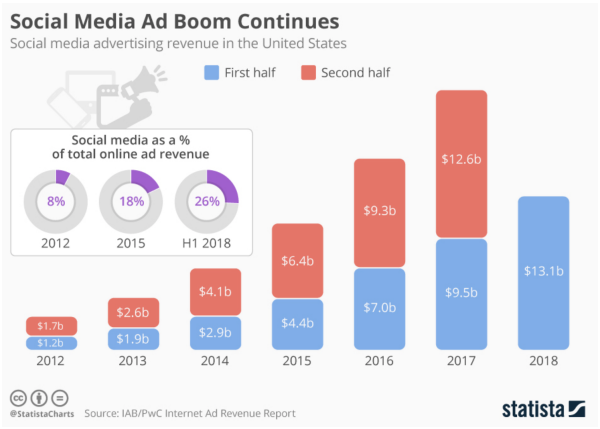

Figure 1: Social media advertising revenue US [15].

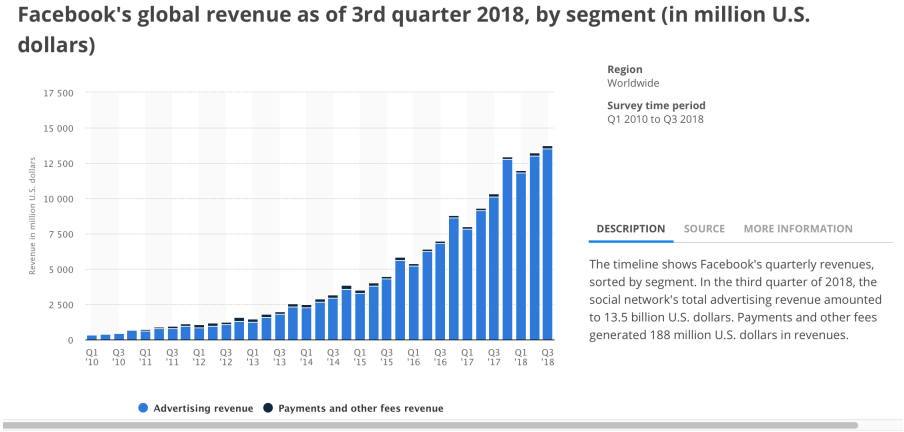

Figure 2: Facebook globl revenue [15].

1.3 Awareness

Are users really aware that their behaviour and emotions are been monitored and possibly influenced by the inner mechanisms of Social Media Platforms via sentiment analysis tools such as the "like" button? In order to answer this question and to preform a review of the literature on the topic we have created the follow questionnaire. The goal of the questionnaire has been to evaluate the awareness that an average Social Media user has in relation to three core topics:

1. Manipulation of or influence on the user's behaviour by the Social Media platform
2. Manipulation of or influence on the user's sentiments by the Social Media platform.
3. Awareness of the extent to which data is collection in terms of privacy and usage.

1.3.1 Questionnaire

Hypothesis

The formulated hypothesis are:

- **H1**: Users are not always aware of the extent to which their data is collected and used.
- **H2**: The Social Media platform influences user behaviour.
- **H3**: Users like to express their emotions on Social Media platforms
- **H4**: The emotional state of users has been effected by the feedback they have received on Social Media platforms.
- **H5**: The users demographic does not influence the previous hypothesis

Data Collection

The questionnaire has been completed by 118 participants ranging from UPF MIIS master students, to colleagues, acquaintances, friends and family members to whom the link has been provided via Facebook, Line, LinkedIn and WhatsApp.

Participants Profile

The following describes the profile of the participants who participated in the study:

	Categories	Frequency
Gender	Female	67
	Male	48
	Preferer not to say	3
Age	< 18	0
	18 - 25	4
	26 - 35	26
	36 - 45	60
	46 - 55	23
	> 56	5
Occupation	Student	9
	Employee	105
	Others	4
Social media Usage	I don't use any kind of Social Media	0
	<1 hour	32
	2 - 4 hours	75
	5 - 8 hours	10
	> 8 hours	1

Figure 3: Participants profile

2 Research Methodology

Nowadays, there isn't any theoretical framework that describes the inner mechanisms of the Social Media for manipulation and exploitation of the user's sentiment or even about the user's awareness of this manipulation. This is the main reason why we decided to perform and Inductive Research Methodology with a theoretical - empirical approach in order to answer the formulated research questions previously mentioned.

2.1 Why Inductive Research Methodology?

This method aims to develop a conceptual framework by looking at the pattern of some observations or research questions (Figure 1)[9].

Figure 4: Induction Research Method

In the scope of this research we aim to point out some interesting concepts that will allow in future works the development of a conceptual framework related with 1) the manipulation mechanisms of the Social Media and 2) the awareness of the user to this manipulation.

2.2 Why a Theoretical Approach?

A theoretical approach or in this case a literature review, is the work conducted to evaluate the state of the art of the researched field. Despite of that in this specific research there is no state of the art for the chosen topic there is some information about Social Media mechanisms for manipulation, sentiment analysis or user's awareness.

First of all, we gathered information from some papers related with the topic. Later we filter them and kept the most relevance for the purpose of the research. Finally little by little, a theoretical structure where all the concepts fit arose, creating a theoretical sphere that will possibly facilitate the postulation of a new theoretical framework.

2.3 Why an Empirical Approach?

An empirical approach is one in which knowledge is gained by observing and measuring a phenomena rather than a theory.

In the conducted research it has been decided to apply this approach because there are not any theories or paradigms about the user's awareness of any kind of manipulation via Social Media platforms on which to rely. We determined the most effective approach to be a questionnaire that tries to measure the user's awareness of: their privacy, the knowledge of the collected data usage and the manipulation/influence of the Social Media in their behaviour.

Despite of been a empirical method it is not considered a scientific one because:

1. The data obtained has not been tested or analysed in any statistical way.
2. The plots created as a result of the questionnaire provided in the Results section of this paper don't contribute to answering the formulate research questions, but rather show the tendency of the answers of the participants.

3 Results

As we can see from figure 3 most of the respondents have stated that they use Social Media for the purpose of keeping in touch with friends and family, they have also stated that the use social media for entertainment purposes but on the contrary, most state that they do not use the platform to meet new people.
Almost 70% of respondents have stated that they use the full range of reactions provided, thus providing a source of information relating specifically to their emotional reactions to specific topics, as users they understand that we are providing some level of information for public consumption but are not fully aware of its potential uses either now or in the future.
Many of the respondents claim to experience some form of emotional fluctuation depending on the feedback received from friends and followers on their social media platform of choice and a significant number claim to unfollow those with whom they do not agree with in terms of political and social views
Many of the participants do not have a significant number of friends of different race or ethnicity and use the social media platform as a major source of news, all factors which may compound the "echo chamber" effect. Finally, it is interesting to note that though most of the participants are aware that the Social Network collects information for advertisement purposes, few participants have declared that they have not actually read the user privacy policy on the platforms that they use.

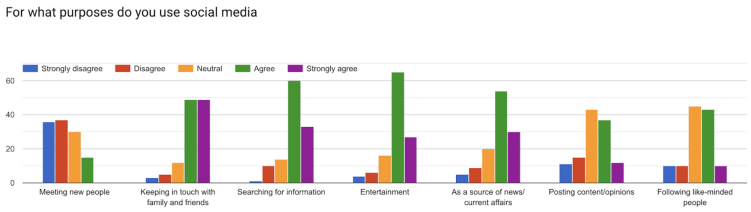

Figure 5: Results: Purpose of Social Media

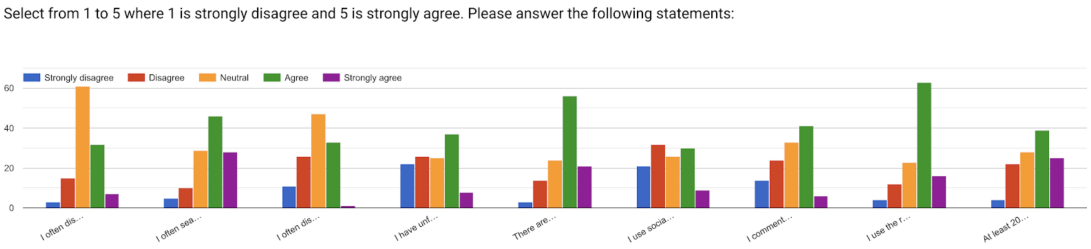

Figure 6: Results: Interactions

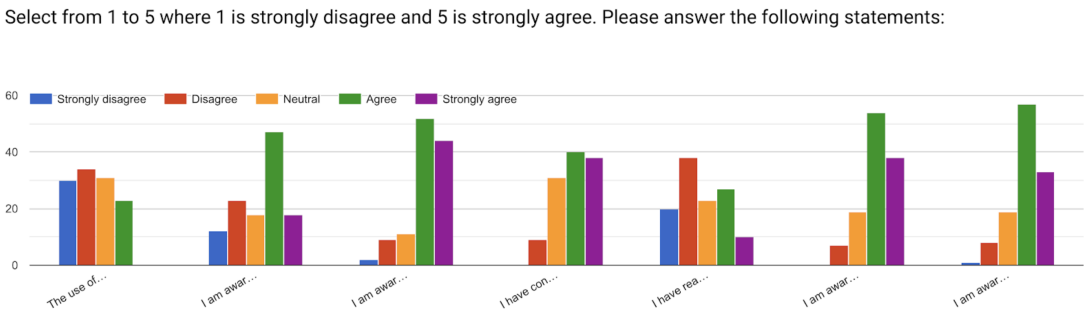

Figure 7: Results: Privacy and data usage

From 1 to 5 where 1 is strongly disagree and 5 is strongly agree, answer the following statements:

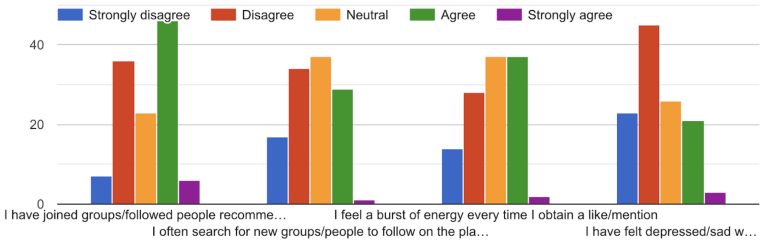

Figure 8: Results: Influence on Social Media

4 Conclusions

Humans have a fundamental need to belong and a fundamental desire for social status. Social networking sites grab us because they involve self-relevant information and bear on our social status and reputation [6]. On social media platforms, what can be seen on individual's feeds is not every post by every friend but rather content carefully curated by an algorithm which determines what content users see, according to the algorithm and commercial interests [13]. To increase the likelihood that friends or fans will see the posts, corporations paying for this and it is a big part of how social media platforms generate revenue.

People with the same interests or views interact primarily within their own group. They seek and share information that conforms to the norms of their group and tends to reinforce existing beliefs [11] [12]. It is where echo chambers occur. People inside the echo chamber will believe that this is all there is. Social media platforms facilitate the entry to the echo chambers more easily than ever before. Individuals are exposed more and more to information and ideas that the algorithms determine they agree with the purpose of retaining engagement and profit and to facilitate this process the platforms are collecting more information than ever before.

People express their emotions naturally in social media, knowing the users' emotions are useful in many others area. e.g. marketing, politics, online shopping, and so on [10]. The companies want to better determine when customers' emotions and when they can be most profitably up-sold by taking advantage of the great amount of user data stored and accessed through social networks, in order to hit the right targeted consumers for sending news, promotions, recommendations, advertisement etc., understanding user's emotions have been studied by analysing all of those data and information e.g. texts in their comments, like buttons' usage, used emoticon etc. to know if an individual has positive, negative or neutral feeling. When dealing with users and sentiments, it is useful to know the users' emotional state, behavior variation, changing of mood, specific actions at a certain time to provide the recommendations and advertisement at the right time.

The more interactions to social media users have, the information are collected to the platforms. As someone who knows things about us has some measure of control over us, and someone who knows everything about us has a lot of control over us [5].

The main concerns are using social media have actually broaden or narrowing people perspective. While we are exposing ourselves to social with lots of interactions, we are selling ourselves to social media platforms or we are the product of the platform that have been sold to the marketers.

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Appendix: Questionnaire questions

Social Media and Online Social Network usage patterns

How many hours do you spend on Social Media/Online Social Network per day?

- I don't use any kind of Social Media
- < 1
- 2 - 4 hours
- 5 - 8 hours
- > 8 hours

For what purposes do you use social media. From 1 to 5, where 1 is strongly disagree and 5 is strongly agree. Please answer the following statements:

- Meeting new people
- Keeping in touch with family and friends
- Searching for information
- Entertainment
- As a source of news/current affairs
- Posting content/opinions
- Following like-minded people

Interactions

Select from 1 to 5 where 1 is strongly disagree and 5 is strongly agree. Please answer the following statements:

- I often disagree with political/social content posted by friends.
- I often search elsewhere to confirm political/social information I read on social media.
- I often discover information on social media that has changed my opinion on political/social issues
- I have unfollowed 'friends' whose on-line opinions I have disagreed with.
- There are diverse opinions within my social media group
- I use social media as my main source of news
- I comment on posts or take part in conversations on social media

- I use the range of emotions provided by any "like" button provided by the social media platform
- At least 20% of my social media group are of a different race or ethnicity than myself

Privacy and data usage

Select from 1 to 5 where 1 is strongly disagree and 5 is strongly agree. Please answer the following statements:

- The use of Social Media influences the manner I behave such as imitating the influencers or people I have followed
- I am aware that social network platforms collect information in regards to the remaining storage space and battery level of my device.
- I am aware that all of my posts, posts' reactions (like, love, angry, etc.), shares, comments, interests, joined group, surfing's behavior, click, page navigation, interests, privacy settings etc. are used for the purpose of targeted advertising.
- I have concerns about my information, comments, shares, surfing's behavior, privacy setting etc are being used and analyzed by social network platform.
- I have read the user privacy policy of any platforms I use.
- I am aware that platforms collect information about the people, Pages, accounts, hashtags and groups I am connected to and how I interact with them
- I am aware that platforms collect information about how I use their products, such as the types of content I view or engage with; the features I use; the actions I take; the people and accounts I interact with;

Influence of Social Media

Select from 1 to 5 where 1 is strongly disagree and 5 is strongly agree. Please answer the following statements:

- I have joined groups/followed people recommended by the platform
- I often search for new groups/people to follow on the platform
- I feel a burst of energy every time I obtain a like/mention
- I have felt depressed/sad when people did not response on my posts/shares.

Bias in Machine Learning

Past impact and current trend

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Abstract. Algorithmic bias has been pushed to the forefront of both the scientific literature and mainstream media, as artificial intelligence is widely adopted in our daily lives. However, the literature is relatively scattered and there is not consensus on how to define or assess it. We analyze the scientific production on the algorithmic bias, and identify three different types of research on the topic, based on its purpose. This allows us to describe the evolution and current state of the subject, and to discuss and motivate further research.

Keywords: algorithmic bias · fairness · machine learning.

1 Introduction

Machine Learning and Big Data are getting more popular with every passing day, up to the point that most companies and institutions find themselves making constant use of algorithms to analyze user data. Accordingly, societal implications of Artificial Intelligence's growth in popularity have attracted the focus of both the mass media and the research community. In particular, there is an increasing concern about how these algorithms can reflect social biases or prejudices, and terms such as *algorithmic bias*, *machine bias* or *algorithm fairness* have been coined in order to describe this phenomenon. Even though, the idea of algorithmic bias has been present in the scientific literature for more than 20 years now [1, 2], but it is since this widespread adoption of machine learning that a need for solid frameworks to study it has shown up [3].

The term bias often has a negative connotation in the English language. However, one can understand a bias as a deviation from a standard or an expected value, which can be seen as an objective property of a particular system. In the same way, in machine learning context bias can be understood as a certain characteristic of a system, either intended or unintended, or as an unfair discrimination on its outputs. For instance, an automatic speech recognition system can be intentionally biased to better understand certain accents, while a risk assessments algorithm can be biased against the black population [7]. Then, it is the latter the one which is commonly considered as algorithmic bias, due to its potential societal impact.

While the challenge of measuring scientific research in terms of quality has been broadly studied over the past decade, it is still not clear how to evaluate its social return [4]. In this sense, although strong efforts are being made in order to discover and mitigate the algorithmic bias [5,6], it is still unclear how to handle the problem, and it is not unusual to find cases where there is not consensus even when it comes to identify it [7, 8]. It is in such cases that the lack of an established framework to characterize and address the algorithmic bias becomes more evident. In consequence, over the recent years a specialized research community has formed, dedicated to the study of the topic: from providing general and domain-specific taxonomies of bias in algorithms [9, 10] to proposing alternative approaches to the problem [11] that could lead to a better understanding of this phenomenon.

Therefore, three main classes of research on algorithmic bias are naturally identified, distinguished by its main purpose: to assess it, to address it, and to provide or extend theoretical frameworks that help to understand it.

In this study we attempt to characterize the status of the algorithmic bias as a research topic and how it has evolved during the past decades, aiming to get a better understanding of its current trend and the challenges it is facing. More specifically, we address the following statements:

- Algorithmic bias has rapidly grown as a research topic since the widespread of machine learning, at the beginning of the decade.
- Despite having attracted the focus of the research community, its focus is still on solving particular problems rather than providing general frameworks.

2 Research Methodology

Despite having been present in the literature for several years now, the concept of algorithmic bias can be represented by many particular forms. Then, in order to study it, it is necessary to define a set of keywords to be used so as to identify the research on algorithmic bias. By reviewing the existing literature we have designed the following keyword set:

> {*algorithmic bias*, *algorithmic fairness*, *machine bias*, *imbalanced algorithm*, *machine learning bias*}

Assuming that it will identify a significant part of the research conducted in the algorithmic bias, and therefore that an analysis based on these keywords will be representative of the whole research topic.

On the other hand, our information sources are academic search engines such as Scopus and Google Scholar, and so we need to define not only the keywords but the relations between them when we query the databases. While all of them allow the use of quotation marks so that the words are considered as a single unit and searched together, only scopus allows more complex queries, where one can use the AND/OR operators to query its database.

2.1 Evolution over time

The first part of our study is aimed to characterize the evolution of the scientific production on the algorithmic bias over time. For this purpose, only Scopus is considered as an information source, since it allows massive extraction of results, and publication dates are considered between 1985 and 2018.

The keyword set is searched in the title, abstract and keywords of the papers, assuming that any publication that intends to discuss the topic in depth will have at least a keyword in one of these fields. We define two queries for each keyword in the keyword set, with and without quotation marks, so that the keywords are searched together and individually -with an AND operator- across the mentioned fields. By doing this we aim to obtain strongly different results. The first and more restrictive one would guarantee that the output publications are focused on the study of the algorithmic bias, while the second one -and way less restrictive- would serve as a gauge to measure, for example, how often *machine learning* and *bias* appear on the same paper. Therefore, the output of this unrestricted case can be interpreted as publications that mention the algorithmic bias but that are not necessarily centered around it.

2.2 Classification of papers on the topic

In the second part of our study we aim to explore and characterize the scientific production on the algorithmic bias. For this purpose, we consider the following classification of the research on the topic based on its final goal:

Assess. To study, evaluate or prove the presence or absence of algorithmic bias in a particular algorithm or application.
Address. To solve -or provide an approach to solve- the algorithmic bias in a particular algorithm or application.
Theorize. To provide or extend theoretical frameworks aimed to understand or address the algorithmic bias in a general situation.

The searches are performed based on the keyword set and over different digital libraries. For each database, two lists of results are collected, corresponding to the first page of results ordered by relevance and, if possible, number of citations.

In a first experiment, the following digital libraries were explored:

ACM (dl.acm.org/). Keyword: *algorithmic bias*. Queries: relevance and number of citations.
IEEE (ieeexplore.ieee.org). Keyword: *machine learning bias*. Queries: relevance and number of citations.
Springer (link.springer.com). Keyword: *imbalanced algorithms*. Query: relevance.

Each of them was queried with one keyword of the keyword set, while *machine bias* and *algorithmic fairness* were discarded as they were giving many non-relevant results.

Since conducted our research was conducted within three different databases, each of them interfaced with its own search engine, let us briefly discuss the particularities we have encountered on each of them.

ACM Querying a two-word keyword without quotation marks does not apply an AND operator between them, but show a result if only one of the words appears on the article. Therefore, in order to obtain valuable results, we only consider queries using quoted keywords. In this case, this led to an almost complete overlapping of the results obtained by both relevance and citation ranking.

IEEE Strongly different results are obtained when the query is ranked by relevance and by number of citations. This is, in this case we have no overlapping between the results obtained by the two types of ranking, getting different papers with each of them. Moreover, since this library is focused in engineering, the major part of the results does not consider the algorithmic bias as a concept but the *bias* as a parameter of a particular algorithm.

Springer The Springer Library search engine does not allow ranking by citation number, and therefore we only consider the papers outputted by the relevance ranking.

The collected results were then manually analyzed and tagged within the proposed classification, allowing a single reference to be tagged into to classes.

3 Results

3.1 Evolution over time

On Table 1 we present the results of our first experiment, following the method described in Section 2.1. As expected, forcing the words of the keyword to appear together in the search fields leads to a very restricted output, when compared to the unconstrained search. However, both results can give us relevant information about how has the research on algorithmic bias evolved during the past decades.

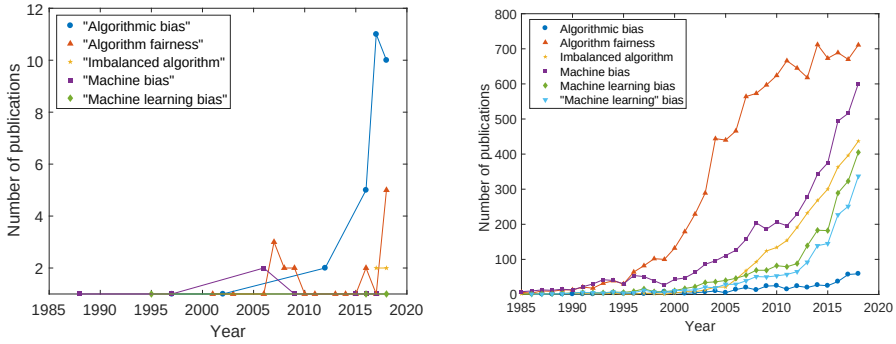
Table 1: Number of publications by different search criteria.

	With quotation marks	**Without quotation marks**
Algorithmic bias	30 (1997 – 2018)	434 (1976 – 2018)
Algorithm fairness	23 (2001 – 2018)	10485 (1962 – 2018)
Machine bias	8 (1988 – 2017)	4872 (1945 – 2019)
Imbalanced algorithms	2 (2017 – 2018)	2899 (1984 – 2018)
Machine learning bias	3 (1995 – 2018)	2249 (1958 – 2018)

In Figure 1a we show the amount of publications by year, obtained when we restrict our search. One can clearly see an increase on the number of papers

published on the topic of the algorithmic bias that starts around the year 2000 and spikes in the last 5 years.

Figure 1b shows the search results in the unrestricted case, where we can observe a similar trend. However, *algorithm fairness* starts its increase 10 years before *machine learning bias*, indicating that this particular keyword may be too general and not relevant when considered without quotation marks, especially considering that the word *fairness* has more than one meaning in the context of algorithms. Despite that, we also observe how in this case the whole set of keywords starts its increase before it did in the restricted case. Then, we could say that while the algorithmic bias has been increasingly mentioned year by year during the last decade, its importance as a research topic did not begin its increase until the past 5 years, which would make sense if one assumes that the first motivates the latter.



(a) Search results using quotation.

(b) Search results without quotation.

Fig. 1: Publications by year.

3.2 Classification of papers on the topic

On Table 2 we present the results obtained after manually tagging the output of the queries we performed, as described in Section 2.2. The full list of analyzed references can be found in appendices A, B and C.

Within this output we found some papers that were considered to be non-relevant for different reasons. Some of them used the keywords in different contexts and should not be considered, while there were conference talk overviews that did not include the presentation itself. In addition, as we mentioned before, some keywords were found to be more specific than others, as *imbalanced algorithm*, that was used in our context only half the time. Therefore, we considered a fourth *non-relevant* class in order to keep trace of this results.

As mentioned in Section 2.2, in some cases we found a strong overlapping between the result sets obtained by the two ranking methods. Then, in Table 2

Table 2: Manual classification of publications from different libraries.

	Relevance			**Number of citations**		**Total**
	Machine learning bias	Algorithmic bias	Imbalanced algorithm	Machine learning bias	Algorithmic bias	
Assess	3	9	3	7	9	31
Address	13	3	4	9	3	32
Theorize	4	7	3	2	7	23
Non-relevant	1	3	10	4	3	21

the results are split by ranking method, meaning that summing the displayed totals in each row will not give the actual number of papers that fell into each category. Therefore, in Figure 2 we plot the distribution of results by keyword and class, relative to the class they were labeled with.

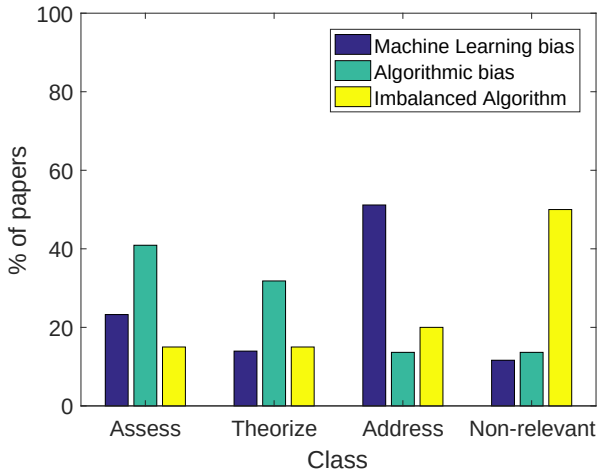


Fig. 2: Classification of the results by keyword. For each keyword, we display the % of results with respect to the label class it was given.

On Figure 2 we see that *address* is the class that receives more results, followed by *assess*. Therefore, one can get an intuition of that the effort put on the study of algorithmic bias has been focused on analyzing or solving particular problems, rather than on building a theory.

4 Conclusions

The study has provided a better understanding about the state of the research on the algorithmic bias. Our results confirm that, while it had its first appearances decades ago, the topic has become a focus of study in the recent years, with the number of publications growing rapidly after 2010.

After manually classifying several papers from different digital libraries to gather the kind of research that is being conducted, we have seen that there is a strong effort being put on detecting and solving biases, while there is not a standard for what constitutes a biased algorithm, or an established methodology for creating fair artificial intelligence.

There is still a lot of discussion about the difference between an algorithm designed to work on a particular collective within the population and a biased one. In further work we may discuss wether or how the field would be able to find a unified standard for algorithmic bias, or if this research will instead continue being conducted on particular cases. It would also be interesting to compare the existing proposed methodologies for evading bias and see if they are robust enough to generalize to the entire machine learning field.

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Awareness of the Internet of Things research regarding security and privacy risks

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Abstract. The internet of things (IoT) refers to the binding of everyday devices to the internet. This approach will revolutionize the way we interact with daily service providers, from personal and domestic accessories, up to public transportation and power grid infrastructure of cities. Data overcollection coupled with weak encryption capabilities of the net-connected devices puts at stake the right for privacy of the users, thus research and development of this novel connections and interactions must be contained in order to meet security requirements. In this work we aim at studying the awareness on these issues in the field. To that end, we analysed the 30 most relevant papers of the IEEE IoT Journal, the most impactful journal on the topic. We found that despite IoT has the potential to cause a change of paradigm on society, serious security and privacy concerns are often left aside by researchers.

Keywords: Internet of things, data security, privacy, data overcollection, connectivity, social rights.

1 Introduction

The Internet of Things (IoT) is a concept integrating the virtual world of information technology with the real world of “things”[1]. Its main goal is to optimize human life and sustainability by creating “smart” grids via intelligent information transmission. This digital revolution promises immense and prosperous societal benefits resulting to an exponential growth in demand with a corresponding financial growth in market share. However, experts in the field are often narrowly focused on technical aspects and neglect potential social impacts and hazards. This paper aims to investigate the social awareness of leading researchers in the field in terms of security. As IoT is a broad and commonly misused term, this chapter will initially provide the fundamental aspects behind this technological concept.

IoT describes a dynamic global network infrastructure of devices (things), digital communication protocols and human adaptation that establishes an interconnectivity within the infrastructure via bi-directional data transmission and communication. The term was initially introduced by the Auto-ID Labs of MIT in 1999 for a very specific

technological device, Radio Frequency Identification Devices (RFID)[1]. Nowadays, the definition is extended to describe the networking architecture between sensing devices, transceivers and end user digital interfaces monitoring and controlling received information in the Internet cloud. Most of the current deployed IoT solutions offer fine-grain data visibility for human end users while developments in Artificial Intelligence (AI) intend to empower “things” with virtual personalities and autonomous behavior. An IoT infrastructure offers an interconnection of exchange of information at several layers. Thus, cyber-attacks can occur at multiple levels of this information transmission and control flow; from the physical layer to the cloud.

A general control flow for an IoT infrastructure begins with the sensing device itself specifically designed to acquire the desired information. Considering the developments in Nanotechnology and Microelectronics these devices can be embedded with a microcontroller, transceiver and antenna at a very small scale. The integrated unit digitizes the sensed analog information from the environment and sends raw bit packets of information at a specific frequency and bandwidth to external receivers (gateways) [2]. These raw data packets are usually encrypted prior to sending by the embedded unit with standard encryption protocols such as the *Advanced Encryption Standard 256 (AES 256)* [2][3].

The gateway receives the signal after decoding it from multiple sensing units and transmits the re-encrypted information to the cloud via various communication protocols such as the General Packet Radio Service (GPRS) [1]. The packets of information are decoded by a digital interface connected to the *Internet Protocol (IP)*. The end user can monitor the data and communicate back with the devices to make requests. This is a typical control flow for “smart” utilities in cities such as electrical and water supply networks.

According to the demands of the desired infrastructure there have been multiple technologies developed. The main parameters to consider for an IoT solution is the required range, coverage and capacity planning, electromagnetic spectrum, data rates and security. Considering the percentage of the geographical area to be covered by the cellular service, IoT networks can be categorized to fixed and short range (e.g. Bluetooth) ,long range with *Low Power Wide Area Network (LPWAN)* and *3rd Generation Partnership Projects (3GPP)*[4].

IoT technologies have already started revolutionizing many sectors in human societies as summarized by the *International Telecommunication Union* (ITC)[4]. Smart solutions in utilities such as automatic metering, energy and production optimization, planning demand, advanced management of water and electricity distribution networks and operations control are essential for improving the city’s sustainability. Solutions like energy optimization, asset management, recycling and power generation and automatic fault detection diagnosis can be utilized in buildings as well. IoT can optimize public services in citizen services, smart tax administration, smart customs, immigration and border management, smart crime prevention, efficient emergency response and smart financial management. In addition, transportation can be optimized with real-time adaptive traffic management, smart parking and tolling solutions. The healthcare industry can benefit through smart medicine supply, remote healthcare management and connected and mobile health. The aforementioned can provide an idea of the enormous diversity of applications and benefits that Internet of Things can offer.

In many cases, IoT solutions transmit and store in the cloud personal information. This information can be often vulnerable to cyber-attacks and in many cases the information can be substituted. Some examples of personal information that can be susceptible is one's health status stored in a mobile application , criminal records, tax status, billing information and real-time geographical location. As an IoT infrastructure is consisted of many layers of hardware and communication protocols data encryption and integrity can prove to be inadequate to protect a human's personal information.

Current research covers a broad range of topics, from smart infrastructures to system architecture. It is mainly led by China and Europe. Most of the research is based in specific technologies and applications, while surveys and challenges occupy 11 and 17% respectively. This already gives an insight in the challenging nature of this field[5].

Considering all the above, Internet of Things is an interdisciplinary concept highly bound with the new generation of telecommunications and shows an immense diversity in applications and technicalities. The quantification of the leading researcher's awareness, regarding the security and social impact of proposed IoT solutions, is investigated in the remaining part of the document.

2 Research methodology

In this project we based our methodology on literature search. To study the awareness of IoT researchers on the social impact caused by their work we decided to gather information from several academic articles to extract conclusions afterwards. Since IoT is quite innovative and is still not completely established the number of journals and information sources is not too broad. Therefore, a decision was taken to focus on a single journal with the highest impact factor on our topic. The journal of our choice was the IEEE Internet of things Journal[6] which as of November of 2018 has a high impact factor of 5.863 and is ranked as the leading journal focusing solely on IoT technology[7].We studied 30 of the most popular papers published on the 2018 edition of the journal to perform a qualitative study of the social impact awareness of the authors by categorizing them according to a set of topics. Since the data comes from a leading journal this method has the advantage of focusing on the latest trends and hottest topics of research on IoT at the moment. This means we manage to get a general overview of the relevance given by present researchers of the field to the social impact and risks of their research. On the other hand, while alternative sources such as opinion articles and interviews might as well address our topic, we believe focusing on the academic literature to be the right choice since it is the most likely IoT knowledge and innovation path that is going to reach the industry and investors, finally leading to its widespread implementation.

As aforementioned we have categorized the data on several groups. First, we divide the articles into the following topic categories:

1) Smart cities 2) Industrial Internet 3) Connected Car 4) Connected Health
5) Smart Grid System 6) Architecture Security 7) Machine Learning

To create the classification, we mainly focused on the objective of each paper. We also looked for specific key words and see if the article presented a specific to tackle privacy and security concerns. Following these criteria, the 30 articles where classified in the categories mentioned above. In this way we aim to observe different kind of concerns in the papers that have been analysed. Moreover, we split the analysis differentiating surveys and papers which present a specific technology. This is done in order to capture the details of the technological papers, while preserving the overview that surveys yield. All the papers used for the analysis have been referenced in the end of the document even if they are not mentioned throughout the report.

3 Results

In this section we present and discuss the results obtained. To do so we represent them as a bar plot where the frequency of mention for each topic is shown. We shall mention that the percentages do not add up to one hundred since one same paper can focus on more than one topic.

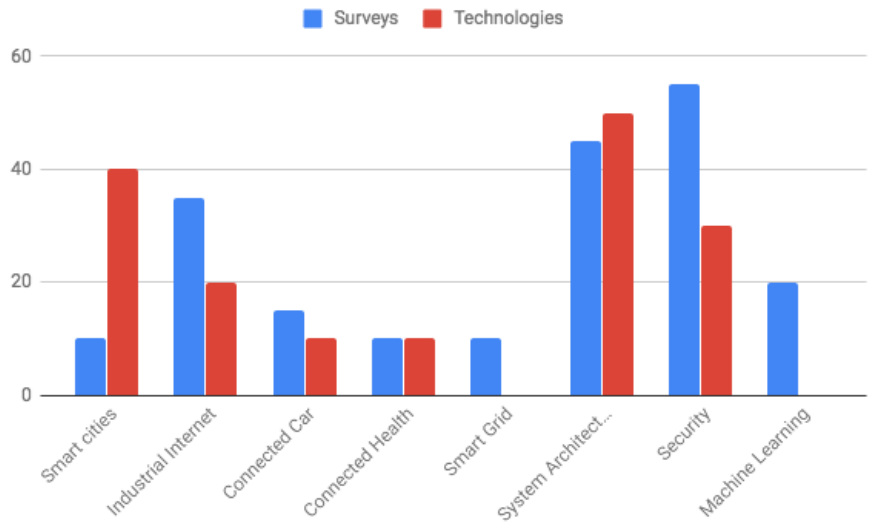

Figure 1. Frequency of appearance of each topic in the analysed papers. The bar plot shows in red the results for technologies while in blue are shown the result for surveys.

Firstly, the surveys focus emphatically on security, being this topic the most frequent one followed by architecture of systems and industrial internet. On the other hand, smart grid and city technologies as well as connected health are the less represented.

We want to stress the urge we found in all of the surveys to communicate the potential IoT researchers the need to consider possible exploits in their research technologies. When analysing the papers one by one, we found out that even those who are not specially focused on security but rather aim at a technology in particular

still mention security and privacy issues. The main ideas shown and repeated horizontally to all surveys are:

A. Relevance of usage privacy and data security protection for IoT.
B. Raise a flag into the obsolescence of the current security paradigm for IoT.
C. Point out that most IoT devices are designed with poor security and privacy protocols.
D. Express the need for technology standardization in order to solve current heterogeneity in data management protocols.

To sum up the overall point of view from the surveys we analysed we would like to quote the paper by Chen et al, where they state: *"Connectivity between the things shall be available to all with low cost and may not be owned by private entities. For IoT, intelligent learning, fast deployment, best information understanding and interpreting, against fraud and malicious attack, and privacy protection are essential requirements."*[8].

On to the papers that introduce innovative architectures, protocols and devices, they don't focus as much in privacy and security issues as the surveys do, despite many of the research presented in these papers has a high risk of negatively affecting the society.

Regarding papers that present novel architectures and protocols to enhance existing technology such as [9][10][11][12], only one is focused solely in security concerns. In [11] the privacy risks of Mobile Crowd sensing are addressed and solutions are proposed for private key distribution and ensure data privacy. In [9] the possible synergy of the security of blockchain and IoT services is studied. However, it is admitted that due to the high number of nodes connected, the extra layer of security brought by blockchain could be rendered useless. Articles [10] and [12] present improved transmission algorithms and innovative architectures for IoT but they do not pay any attention to any security or privacy concerns these improvements might bring.

Nevertheless, since this group of articles is just focused in innovative technologies in early development stage, we consider these cases not to be as serious as the articles about innovation in urban IoT, which is said to soon be implemented all around the world. This technology is said to be crucial for an effective implementation of the Smart City vision which aims to make a better use of the public resources to improve public services such as transport, lighting, garbage collection, surveillance and maintenance while reducing the operational cost of public administrations [13]. However, this rises big concerns on data privacy and threats to smart city systems.

All connected data devices need to be smart enough to recognize different users and avoid any data breach and exposing sensitive data from the users [14]. With this concerns in mind out of the four papers focusing in Urban IoT and Smart Cities none of them even slightly mention any privacy or security risks of their research. In [13] a set of Smart city applications for IoT are proposed, just a slight mention is made to the risk that a network of Noise pollution control sensors can pose to the privacy of the citizens. In [15] innovative programming model is presented for IoT service developers. Several case studies are proposed such as the development of a video surveillance system for stadiums with real time analytics, but no considerations are

included about the risks of such a control mechanism nor the security to protect the collected data.

Not a single mention is made about the privacy and security concerns of the public. The same can be said for articles [16][17] were a system to localize people inside a building and a noise monitoring system are proposed. Both of these ideas require a big network of sensors that directly puts in risk sensitive data of citizens if the security and privacy concerns are not taken seriously.

The field of Connected Health seems to be the field most aware about all of these risks perhaps due to long time discussion about patient data privacy in healthcare. An architecture to connect devices in a smart hospital is proposed[18]. Every section of the article addresses privacy and security issues even at the different layers of the architecture from the sensing to the cloud layer. Moreover, future work is directed towards the development of improved encryption, identification and authentication mechanisms.

Acknowledging the exponential growth and implementation of IoT in the next years we think these findings among these articles to be quite worrying. Papers that present new architectures and protocols seem to be quite oblivious to the exposure of the sensitive data of their users. At the same time, we feel that papers that propose applications to surveillance systems should include an ethical discussion.

To conclude the analysis of results, we will compare both surveys and technological papers. Relating to the mere frequency of the topics, we found some correlation in the system architecture, connected health and car and in a minor way industrial internet. On the other hand, the largest disparities are found in smart cities and security.

We find the disparity in security to be the one which should gain more interest, since all of the surveys, regardless of their focus or not in security, mention the need for secure and private connections in order to make IoT advance, whereas the technological papers do not.

One clear clash of ideas is found in the smart cities case, where technological papers do not mention security and privacy issues at all despite there is a survey specially dedicated to pose the risks and challenges these technologies need to face.

4 Conclusions

This work had the main aim of analysing the potential social impact of future implantation and expansion of IoT on society. More specifically, we wanted to focus on the security and privacy concerns brought by the simultaneous connection of millions of devices uploading huge amounts of personal data to the cloud. For that purpose, we reviewed 30 of the most popular papers from the IEEE Internet of Things Journal, the most reputed journal in its field by classifying them according to their type and the topic.

The conclusions we draw from this analysis are that the IoT research field is in fact aware of the security and privacy risks this technology has since all of the reviews had at least a section dedicated to data security and user privacy. On the other hand, technological papers fail at disseminating the flaws and possible exploits of the

breakthroughs they present, which can be a dangerous approach and will in fact decelerate the rhythm at which IoT could be developed.

All in all, we consider that IoT will be a revolutionizing approach and will be able of providing a broad range of low-cost service while democratizing other services. For this to happen while protecting the user's rights, fields such as IoT for smart cities should be more aware of the new cyberthreats the technologies can create.

The results and conclusions drawn from this work should be kept as preliminary. As further research the body of work analysed should be increased considerably in future works in order to obtain reliable and reproducible results. Nevertheless, at the moment there are no other benchmark journals apart from the one analysed in this work.

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Bias and other Problems in Quantifying University-Industry Research

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Abstract. This article analyses the existing metrics used for quantifying university-industry joint research. The mentioned metrics are difficult to implement, mostly due to lack of publications based on confidentiality agreements. Therefore, metrics proposed by researchers tend to be adapted to the little information available. Results derived from these metrics generally end up being highly biased or presenting other type of problems. This article also proposes a new metric derived from the previous ones.

Keywords: Research · Quantification · University · Academic · Industry · Joint Ventures.

1 Introduction

Research conducted by university researchers funded by the private sector or in the frame of a university-industry collaboration are one of the main channels through which science and technology are transferred from the academic world to industry [1]. Moreover, the importance of university-industry collaboration has not stopped growing in the last fifty years in the industrialized world [2].

The study of these mechanisms is key to encourage economic development. In the past, many articles have focused on reviewing the interaction between universities and industry and the benefits derived from it [3].

As there is not a unified metric that quantifies these collaborations, authors tend to define their own ad-hoc metrics which are based on the limited available data. Nevertheless, there does not exist a unified metric that quantifies this collaboration in both quantitative and qualitative terms.

Metrics based on the number of citations are suitable for measuring the quality of long term disinterested research as driven by university [4]. Economic viability or revenue are metrics suitable for measuring industry's research from an economic point of view [5]. The aim of this article is to propose a new metric which is capable of linking both terms.

In 3 we analyze previously used metrics and discuss their convenience. In 4 we will draw our conclusions and present how the new metric should be.

2 Research Methodology

This article has two different objectives. On the one hand, it studies the suitability of existing metrics used for quantifying university-industry research. On the other hand, it proposes a new metric. Research methodology of both parts will be discussed separately.

In order to analyze previous metrics, a bibliographical research is executed followed by an analysis of each of the metrics. As data is limited, the different metrics are discussed from an qualitative point of view. The criteria to select those metrics is:

- Being defined in papers published after the year 2000, in order to avoid out of date methodologies.
- Including a high amount of description.
- Having factors indicating that the author has a clear intention to use a generic metric, in order to escape from too specific models.

In the second part, the methodology is different. As no kind of data is available, deduction and the experience gathered in the previous part is used to derive a new metric.

3 Analysis of existing metrics

The results of the bibliographical research are presented in this section.

3.1 Industry Involving Scale (IIS) [6]

Hypotheses and objectives:

1. "University researchers who have active grants and contracts will be more likely to work with industry."
2. "Among university researchers who already receive industry grants will be more likely to work with industry than will researchers who only have government grants and contracts."

Definition of the metric: The developed metric is a weighted sum over different indicators. The weights or the importance of each indicator is based on data retrieval. Each indicator corresponds to a type of industry-research collaboration activity. These are the following:

- A private company asked for information about a specific research and it was provided.
- Contacted persons in industry about their research.
- Served as formal paid consultant to an industrial firm.
- Helped place graduate students or post-docs in industry jobs.
- Worked at a company as owner or employee.

- Worked directly with industry and the work that resulted was a patent or copyright.
- Worked directly with industry to commercialize or transfer technology.
- Co-authored a published paper with industry personnel.

The weight that each of these indicators has on the metric corresponds to its negative frequency. In this case frequency is obtained through a survey and is the proportion of researchers that reported being engaged on that specific activity. For example, the activity "Co-authored a published paper with industry personnel" was answered positively by 15.5% of the researchers. Thus, the weight of engaging in this activity is $1 - 0.155 = 0.855$. With this metric, the values of the total scale ranged from 0 to 6.58. The mean score of the researchers in the dataset is 1.09.

The weighted scale with inverse coefficients is used because this way indicators that are rarely present have greater importance than others.

Target/data origin: The data employed in this article comes from the Research Value Mapping Survey of Academic Researchers, a study from Georgia Techs Research Value Mapping Program (RVM). Only a subset of the whole data was used, corresponding to academic researchers working in universities that produced at least one Ph.D. in 2000 in at least one of 13 science and engineering disciplines.

Conclusions about the suitability of the metric: On one hand, we find that the method for assigning weights is not entirely convincing in order to measure research quality. In fact, this metric measures rarity, which is not a common feature in research analysis.

Eventually, the dataset used is probably biased towards a subgroup of researchers that collaborated in a university-industry joint research.

3.2 Climate for Academic Freedom (CAF) [7]

Hypotheses and objectives:

1. "To develop a psychometrically sound measure of climate for academic freedom".
2. "To assess whether the source of research funding is associated with the structure or nature of the students research experience."
3. " To assess whether the source or form of research funding is associated with various outcomes, including the perceived climate for academic freedom".

Definition of the metric: In order to understand what influences the climate for academic freedom, some variables where gathered, including: information about the funding source, student descriptors, influence on research, interactions with the research sponsor and the nature of the research.

Then an informal survey of faculty members was conducted to identify dimensions. These activities suggested three dimensions: freedom to choose methods/questions, freedom to communicate results, and freedom to interpret results.

Finally, a pool of items was developed for each dimension and discussed informally with faculty and graduate students. These items were reviewed balanced as positive or negative items.

Target/data origin: The sample was limited to universities that participated in the IUCRC Program (IndustryUniversity Cooperative Research Centers Program). Universities were stratified by percentage of R&D funding obtained from industry. The sample was limited to two engineering departments, chemical and electrical.

Conclusions about the suitability of the metric: As the information was restricted on universities belonging to the IUCRC Program, the data collected is extremely likely to be biased.

3.3 Co-authorship publications (CoAP) [8]

Hypotheses and objectives:

1. "The development of a national mapping system for publicprivate collaboration"

Definition of the metric: In order to map industry-research collaboration in Italy, the authors of this paper use the total number of scientific publications in international journals that are co-authored by universities with any other type of organization: other universities, public research laboratories, domestic companies, organizations from other nations, etc. and the percentage of those publications compared to the total number of scientific publications in Italy; separated by scientific fields.

Target/data origin: The source of reference is the Observatory of Public Research (*Osservatorio sulla Ricerca Pubblica*), that selects most of the publications with at least one address corresponding to an Italian university.

Conclusions about the suitability of the metric: As the authors also discusses in their article, the co-authorship does not represent all the industry-research collaboration as part of the research is not end-up published. However, it has the advantage of being based on objective quantitative data in a form of full census of its target.

4 Discussion and Proposed metric

From the example of the three selected metrics we can see how complicated metrics which look to very specific features such as the **IIS** [6] or alternatives that are very limited in data and suffer from bias like the **CAF** [7] can hardly be extendable to other studies. Nevertheless, other cases such as the **CoAP** [8] seem to have promising options to became a widely used metric.

If we take a look to what types of metrics have been settled as referents in similar fields such as in pure research, we can note some common factors that are present in all of them:

- Generality: well known metrics use data that is available in all the subcategories of the field we want to analyze. As an example, citations is an element present in research no matter what field we are looking for.
  In the research-industry collaboration, common factors we could find would be
  - Co-authorship of companies in published papers.
  - Amount of funding received from private companies in research projects.
  - Number of research projects that involve some type of industry collaboration.
- Balance between quality and quantity: metrics that only take into account quantity are usually left in the background, whereas indexes such as the H-index [9] have a large sharing inside the research community due to their well studied balance between the quality and the quantity of their studied field. Another example of a metric like that would be the G-index [10].
- Easy access to the data: when a metric starts to be used by important media such as *Scopus* or *Google scholar* [11], this metric has finally reached its consideration as a good metric. But those type of media cannot handle metrics that are hard to use, as they have to apply their ranking criteria with a very large number of elements. Thus, if a variable needed in the metric is hard to obtain, this metric will hardly get to the top.
  Furthermore, the accessibility of the data also helps to avoid biased information, as it facilitates to bypass generalizations made from small samples. Because biased data is a common problem we have found in most of the metrics studied for this paper, we should have a special attention to this condition.

Taking this in consideration, The last point automatically sends us to better use data that comes from universities. As most companies tend to not answer when surveyed [12], and the information about their collaboration with research is usually not published.

All three variables presented in the first point meet this accessibility condition. The number of papers with co-authorship of a company is probably the the best suited of the three as a side of its good capacity as quantitative indicator, it also has a little bit of qualitative elements in it: A paper published means that the research has gotten to at least a certain point.

To completely cover the balance discussed in the second point, we should go further and consider also two-variables metrics. The fact that publications are made in a Q1 journal or not is often taken into account for evaluating the quality research [13]; with this, we finally propose the following two-variables metric:

- ***Number of papers' citations with co-authorship of a company.***
- ***Number of papers with co-authorship of a company published in a Q1 journal.***

As it matches all the constraints expressed in this paper (*Generality*, *Quantitative-qualitative balance* and *Accessibility*), this double variable indicator should have the capacity to easily compare the research-industry collaboration between regions (e.g. USA vs EU), universities, or even companies if taken with high level of details.

Tables 1 and 2 show an example of an hypothetical ranking realized to compare research-industry collaboration between regions, where `region 1` seems to be the region with the most collaboration but only in a quantitative way, as `region 2` has the best performance qualitatively speaking.

Rank	Region	Citations of **CoAP**	**CoAP** published in Q1 journals
1	`region 1`	32560	33
2	`region 2`	23853	39
3	`region 3`	4792	7

Table 1. Example of a ranking using the first variable

Rank	Region	Citations of **CoAP**	**CoAP** published in Q1 journals
1	`region 2`	23853	39
2	`region 1`	32560	33
3	`region 3`	4792	7

Table 2. Example of a ranking using the second variable

Eventually, we should note that the number of citations and scientific papers published have different orders of magnitude depending on their field [14]. Then, this indicator should be applied separately regarding this criteria. Nonetheless, this might not be a problem for its future use as it is already done in pure research and it doesn't cause many troubles.

5 Conclusions

In order to be used in a large scale without losing relevancy on its application, a good metric to quantify the research-industry collaboration should meet the three conditions of Generality, Quantitative-qualitative balance and Accessibility.

Nowadays, there is still not an index that meets this criteria and is considered as a reference by researchers. In general, large scale data is very hard to obtain, and most of the conclusions that derive from it have a risk to suffer from biased information.

In this paper, we have proposed a two-variables metric that could meet the conditions for bypassing the issues faced until now. However, as the lack of data is usually the biggest issue for the development of a reference metric, the private sector has a limited capacity to solve the problem. Hence, it could be a good opportunity for large institutions such as the European Union to take the lead.

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Key factors that affect music technology spin-offs in the Music Technology Group at Universitat Pompeu Fabra

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Abstract

Spinning-off from academic institutions represents a challenge for new researchers. The music industry is in continuous growth, bringing opportunities for entrepreneurs to transform knowledge into business. Spin-offs emerge from a high risk environment and are affected by several key factors that could influence on their success or failure, and some of them are related to their parent institution. The paper case studies the four spin-offs growth at the Universitat Pompeu Fabra's (UPF) Music Technology Group (MTG), making a comparison between them and a current existing stage model of spin-offs, conducts interviews with people who involved in creations, also gathers information about the University innovation policies. The study highlight how any spin-off at it early stages got the ideal support from the University, especially in business management, and explains how two of them ended as Small or Medium size Enterprise (SME), another is about to close and the remaining one reached a major success in the global industry.

Keywords: Spin-off; UPF; MTG; Technology Transfer, Music technology

1. Introduction

Music technology spin-offs represent a great portion of the music entrepreneurial initiatives. Innovation can be conducted in many ways, and the nature of the academic research transferred from the university to the new venture can be classified as technology transfer, licensing and spin-offs [1]. Spin-offs are defined as new firms created to exploit some knowledge, technology or research results developed within a university and made it commercial. Our research is mainly focused on the spin-off nature of knowledge transfer in the music technology field and it describes the implications and roles of individual entrepreneurs in spin-offs created in the Music Technology Group (MTG) at Universitat Pompeu Fabra (UPF).

A spin-off implies a series of crucial factors on its creation, which includes the status of the individuals involved in the new business venturing process and the nature of the transferred knowledge. Venture initiatives are often affected by a high risk changing environment, and the situations these ventures need to face every year is a challenge. We observed a gap between researchers and the industrial framework, as those researchers who are interested on building spin-offs aren't always able to find the necessary resources and the correct information to overcome all these difficulties. The first decade of a spin-off is decisive in their existence, most of firm sizes increases at this point and continue achieving the expected market growth and most of them disappear during the process, due to factors that implies a bad management of the resources, not to have the expected revenues and to present inconsistencies in the product generation process. Is observed that academic spin-off ventures created outside established high tech clusters tend to be Small and Medium size Enterprises (SME), due to the lack of information and support from the local institutions, which is affecting considerably to their growth. [2]

F.N. Ndonzuau et. al. described a model of how an academic spin-off is created, proposing four stages that represents the evolution of the idea from the "result of a research" to the "creation of the economic value" (Table 1). On every stage there are key factors that are important to advance, the final state of every stage will be the initial state of the next one. This model is used in this paper to evaluate the spin-off, because it is mainly focused in the initial years, which is critical for the success of a spin-off. [12]

Table 1. A stage model of academic spin-off creation [12]

Stage	Important Aspects
To generate	**Initial state:** Result of research. **Key factors:** - The academic culture. - The internal identification. **Final state**: Business ideas.
To finalize	**Initial state:** Business ideas. **Key factors:** - Protection of ideas. - The development of business ideas - Financing. **Final state**: New venture projects.
To launch	**Initial state:** New venture projects. **Key factors:** - Access to resources. - Relationships with the university of origin. **Final state**: Spin-off firms.
To strengthen	**Initial state:** Spin-off firms. **Key factors:** - The relocation risk. - The change of trajectories. **Final state**: Creation of economic value.

There are basic archetypes to measure and describe the different existent policies that affects to spin offs. These archetypes advert about the situations that can be presented at the time of create and grow an entrepreneurial venture initiative. The importance of the engagement between the researchers, the academic institutions and the local innovation policies are crucial in the knowledge transfer processes and to support this collective during the process of transforming knowledge in marketable products and companies still is needed. [7][2]

Jean-Jaques Degroof et. al. established four main policy archetypes from “complete absence of spin-off policies” to “high support and selectivity policies”. Every archetype affects the spin-off companies differently, especially on three different phases: Origination, concept testing and start-up support (Table 2) [2]. These three phases could be rearranged into the four stages model proposed by F.N. Ndonzuau et. al. in the table 1, as they share similar factors. The work of Jean-Jaques Degroof et. al. is focused in weak entrepreneurial infrastructure, and even though the UPF and the MTG are located in the @22 district of Barcelona, one of the most important technological districts in Spain [13], the descriptions still applies to our case study.

Table 2. Spin-off policy archetypes in universities [2].

Archetype	Characteristics
First	- Total absence of spin-off proactivity. - The initiatives come from individuals and their interaction with industry. - Venture creation before concept testing.
Second	- The support and selectiveness is minimal. - Focus on encouraging spin-off rather than selectiveness, this lower quality of spin-offs - Venture creation before concept testing. - Minimal or none advising from the parent institution.

Third	- Pro-active opportunity search. - More selectiveness by pressuring researchers to be more ambitious. - Intellectual property support. - Management support. - Network support through financial partners. - Venture creation after some concept testing.
Fourth	- Pro-active opportunity search. - Very selective on ideas. - Strong capability on intellectual property. - Strong business support. - Venture creation after completed concept testing. - Broad network support, international. - Internal advising.

As in the music technology field we didn't find studies related to solve the described issues, our aim is to elaborate a study remarking the key factors that affect music technology spin-offs in the Music Technology Group at Universitat Pompeu Fabra, at its different stages, analyzing the nature of its activities from the idea to the marketable product [1] and their current situation. Because this study is done in this very specific case, we can't generalize to every spin-off in music technology, but the methodology is thought to be applicable in a broader selection of spin-offs.

2. Literature review

Nowadays numerous centers [5][6] and offices located in Spanish universities, such as UPF Innovation Office, are dedicated to innovation and entrepreneurship, but there is an impediment in the spin-off creation stage due to the information gap between entrepreneurs and those institutions, which made the entrepreneurial ventures suffer from the wrong spin-off policies, and they have to face structural and cultural obstacles. Not all academic disciplines equally generate new firms. [2] Music Technology and the music business are business areas that in general don't have a capacity of investment as other areas of knowledge such as biomedical engineering or energy industry, as Jordi Janer from Voctrolabs pointed out. But in spite of these existing limitations, a clear example is the inventor John Chowning case study, being the person that created synthesis FM patent in 1973 [8] and licensed it with the help of the Office of Technology Licensing (OTL) at Stanford University, being his invention one of the most lucrative patents of the history of the campus, and the second-highest generator of royalties for its OTL. [3][9] [10] [11]. This is an outstanding example of how music technology and IT industry and universities can work together. [3]. It points out the importance of a symbiotic relationship between the district and the University. The key factor of success of Silicon Valley resides in the University's Symbiotic relationship established between both, where local innovation policies are playing a vital role, giving life and support to many of the entrepreneurial initiatives and marketable technologies promoted by Stanford. [3]

It example can be a reference for the local situation in Barcelona. 22@ district, well known as the technological district of Barcelona, and which is being compared in somehow with Silicon Valley in Palo alto California, that is for Stanford the nearest and most important institutional neighborhood and an excellent example of a local district and academic–industry collaboration [3] For numerous spin-offs out there, one of their biggest problem is to get support. Supportive organizations could be really crucial to the future development for the newly founded companies since they could provide not only funding and places but also other resources such as industry networks to grow potential customers or opportunity to the cooperation with influential companies. [3][2]. This is the case of Reactable, which with the local support of the district institutions Barcelona Activa, located their office in the Nou Barris Technological Park, [6] which constitutes an innovation cluster for engineering and technological companies. Institutions as Stanford University located in Silicon Valley and many others located in 22@ district in Barcelona, such as ACCIO or Barcelona Activa, conform the entrepreneurial infrastructure of the city, and are keeping the mission statement to help entrepreneurs to grow their business, providing them the main infrastructure of resources, guidelines, logistics and capital, and the most remarkable thing is that from this symbiosis between the parties involved, is observed that success not only implies the growth of the venture itself, but also the growth of the supporting institutions; clear example as the most of the benefit obtained from Chowning patent went to support research and teaching at CCRMA, that currently employs 14 people and continues developing research in music technology. [11] [10]

3. Research methodology

A study of the early years of the four spin-offs of the MTG is necessary to obtain a broad view on the conditions that existed when they were created, how were the University policies back then and how are they evolving with time. In order to collect the necessary data, it was decided to perform interviews to people that were involved in the creation, foundation or development of the spin-off, and people that are currently working on them. Also a biography research was intended to support the information.

The MTG spin-offs can be chronologically arranged by foundation date, the first one was BMAT in 2005, in 2009 was founded Reactable systems, the third spin-off Voctro Labs was founded in 2011 and finally MusicMuni Labs was created in 2016. It was intended to interview one person per each Spin-Off, but unfortunately a meeting with a representative of BMAT couldn't be arranged due to the limited time and the very tight schedule. Three people were interviewed, Xavier Serra, who is the director of the MTG and has participated in different ways on the creation of the four spin-offs, also he is the head of MusicMuni Labs[18]. Sergi Jordá, the co-founder of Reactable Systems and active member of the MTG [15] and finally Jordi Janer, co-founder of Voctro Labs and previous member of the MTG [16].

The three interviews were done by the authors of the paper and were recorded with the permission of the interviewees to further analyse them. The next step was to elaborate a table (similar to the table 1) for each spin-off. The tables contain important information about every key factor on every stage of the spin-off as proposed by F.N. Ndonzuau et. al.

Also the information related to the UPF's role in the spin-offs was collected, compared and analysed to locate their policies within the four archetypes described by Jean-Jaques Degroof et. al.

Questions about their current status in the music business were also added, in order to analyse the factors that play an important role in their success.

To obtain the key factors that affect to the spin-offs, the correlation with this two approaches was studied in order to explain the outcome, whether the company is currently successful or not.

This questionnaire is found in (APPENDIX A)

4. Results

The three interviewees agreed that there has been improvement in the way UPF support new entrepreneurs since 2005, an innovation department was created and it has been growing since the success of the BMAT spin-off, either way they are limiting itself to legal assessment, minor advising on business management and almost no funding.

The academic culture of the University doesn't show any preference on academic research over applied research, so it brings the opportunity for the researchers to focus their work in market solutions, this is an important factor in the first stage of creating a company. On the other hand, the UPF do not take initiative on the promotion or selection of projects with business potential, it always depends on the researcher to take the lead on presenting an idea to the innovation department. In addition Xavier Serra pointed out that the entrepreneurship culture amongst the community plays an important role, and only a few students and researchers of UPF are willing to start a spin-off. This situation derive in a low probability of a spin-off creations in the University.

Another common ground between interviewees was that, after the foundation of the company, the University only works as a business partner, so practically it doesn't get involved in the creation of the economic value of the spin-offs, neither instigate the concept of product testing before launching the company, and also doesn't take care about the market study at all.

Looking at the table 2, the UPF's spin-off policies can be described by the second archetype. There is a diminishing relation between parent institutions and spin-offs over the time, the phenomenon is described by M. Perez et. al. [19]. Now, all the spin-offs rely mostly on their customers or on the different partners more than on their own parent institution. When the spin-offs are left by themselves in the music industry, they will depend completely on their founder's entrepreneurship skills. In those skills are the keys of their differences and the different outcomes that they present to the market.

VoctroLabs and BMAT are examples of good entrepreneurship. They had a very clear view of the ways to exploit the market with their resources, which is one of the key factors to succeed as a spin-off. BMAT started to provide services of their technology to Yamaha, but then, they started to work in different technologies and expanded their services to a broader level. Voctro Labs started after a collaboration work between the UPF and Yamaha, in which the Vocaloid was created. The Vocaloid was owned by Yamaha, but they got the rights to work with these technologies and implement them in new products. After, when they stablished themselves in the market, they started to offer more products and services. Nowadays BMAT is a medium size company wit more than 50 employees and offices around the world. Voctro Labs is a small company, but presenting a very solid core to keep themselves in the business. Both companies are focused on the increasement of their economic value to experiment a successful growth.

Table 3. Stage model on BMAT [14]

Stage	**BMAT**
Result of research: There were many researchers conducted by PhD students and MTG staff before obtaining the core idea for this company.	
To generate	**The academic culture**: They found a balance between academic research and applied research. **The internal identification**: Researchers identified the outcomes of their work as having a business potential and started to focus on it.
Business idea: The focused on the idea of "indexing all the music in the world"	
To finalize	**Protection of ideas**: The technology was owned by the University and they give exclusive permission to the researchers to use it and share the incomes.The development of business ideas: They decided to spin-off from the UPF, Yamaha was a potential customer from the beginning. **Financing**: The spin-off company had to resolve the financing with external investor after their creation.
New venture project: The spin-off company was created relying on their only potential customer, Yamaha.	
To launch	**Access to resources**: The UPF gave the technological resources through the MTG, most of the financial and management resources came from an external institution or company, and was the responsibility of BMAT to find them. **Relationships with the university of origin**: The founders of BMAT also were part of the MTG, they share part of the incomes as the technology was owned by the University. BMAT and UPF became business partners.
Spin-off firm: BMAT now is an independent company; they start working with Yamaha and enhanced their portfolio of technologies, then buy the ownership of the technology to the UPF and started to expand their business.	
To strengthen	**The relocation risk**: fortunately, the MTG is located in the technological district of Barcelona (@22 District). BMAT move their headquarters close to it, and opened office in 12 different locations around the world. **The change of trajectories**: They evolve from a product oriented small company to a medium size business company.
Economic Value: Their expanded portfolio allowed them to grow in human resources, they're counting on more than 50 employees specialized in specific areas like business, financial and technology.	

Table 5. Stage model on Voctro Labs [16][21]

Stage	**Voctro Labs**
Result of research: Researchers of the MTG were working on vocal synthesis	
To generate	**The academic culture**: From the beginning researchers were doing applied research with intentions on creating a product. They focused on voice synthesis. **The internal identification**: Yamaha partner with the UPF to work on Vocaloid, a virtual singer voice synthesizer.
Business idea: Yamaha was interested only in the Vocaloid. But they found the opportunity to work in collaboration with them to make the spanish version of the virtual singer.	

To finalize	**Protection of ideas:** In this case, the intellectual property belongs to Yamaha because the UPF made the technology transfer reviously. **The development of business ideas**: Voctro Labs intended to get the rights to commercialize this technology in Spain, in projects outside the interest of Yamaha. The UPF provide some advice on how to manage this legal issue through the innovation department. **Financing:** The UPF didn't bring the financing to Voctro Labs.
New venture project: They founded the company and started working with the Vocaloid technology.	
To launch	**Access to resources**: The UPF provide some advising but almost all the resources had to be found by the spin-off team.. **Relationships with the university of origin**: Voctro Labs and the UPF became business partners. The University promotes then mainly in music technology conferences or meetings.
Spin-off firm: The research team started working with voice synthesis based in Vocaloid, they incorporate patents and technology owned by them to provide a variety of services.	
To strengthen	**The relocation risk**: The company is located close to the MTG offices at the @22 district. **The change of trajectories**: Additional to the Vocaloid and the Voiceful products, they started to give expand their economic activity offering technological services and collaborations with research partners
Economic Value: From the beginning, the company was directed by the four cofounders. They are a small but very stable business	

A bad practice will be relying on a single service or product as the case of ReacTable systems. In the interview with Sergi Jordá, he confessed that building up a company never were their main goal. Even though they owned a considerably successful product that made a great globally impact in the music industry, they did not have sufficient skills to manage the company growth, showing these results that they didn't work enough on the economic value aspects of the spin-off.

Table 4. Stage model on Reactable Systems [15][20]

Stage	**Reactable Systems**
Result of research: Sergi Jordá, along other three members of the MTG, were the creators of the Reactable, an electronic musical instrument which allows people create music using blocks over a table. They were demonstrating their inventions mainly in museums and conferences.	
To generate	**The academic culture**: They did applied research to enhance the instrument, but never with a business or economic approach. **The internal identification**: The researcher wasn't intended to make business on top of it, but it became popular and they were force to commercialize it.
Business idea: The Reactable was already tested, now they had to work on how to do business.	
To finalize	**Protection of ideas:** The technology was owned by the University and they give exclusive permission to the creators to use it sharing the incomes. **The development of business ideas:** The UPF paid business and marketing courses to the creators, now they have to do all the market study and the business management. They didn't count on specialized personnel. **Financing:** They rely on the two main start-up supporter institutions from Barcelona: ACCIÓ and Barcelona Activa.
New venture project: They already were popular within the music technology community and artists, they rely on that to start the company.	
To launch	**Access to resources**: The economic and infrastructure support were provide by ACCIÓ and Barcelona Activa. They had a maker space on the "Parque Tecnológico de Poblenou". **Relationships with the university of origin**: Reactable systems and the UPF were business partners sharing the incomes of the company in exchange of the use of the technology developed in the MTG.
Spin-off firm: The Reactable company started to negotiate the instrument and they reached big stages, Björk played it in live concerts in their early days as a business company.	

To strengthen	**The relocation risk**: Reactable systems have an office in Barcelona at the @22 district. **The change of trajectories**: Their peak success was in their early years, even before they were a spin-off company, but they rely only in one product. The problem was that this electronic instrument cannot be commercialized to a broad audience do to its complexity and dimensions. When they started to expand the portfolio of the company offering products for smartphones, they didn't have the specialized people to face this new business approach.
Economic Value: Their star product was intended to a very narrow set of customer, so with time, the economic activity decrease. They tried to change to a wider market but they didn't have qualified personnel to make it. In consequence, they are closing the company by April 2019. Reactable systems had a maximum of 10 employees at a time which is evidence that they always were a small business.	

MusicMuni Labs still is a very young spin-off to know and evaluate if they are being successful or not, but at least it is true that they are supported by a more participative innovation department in comparison with the other three spin-offs cases. In addition as Xavier Serra is the head of the team and he was involved in another spin-off's initiatives they have an experienced entrepreneur on board. They also focus their business in a very specific user target, and they are conceiving and working on several new products and services to offer to their customers. A key point is that MusicMuni has tested the technology before launching the spin-off, so with the time the expectation is to observe a successful growth in the Company.

Table 6. Stage model on MusicMuni Labs [18]

Stage	**MusicMuni Labs**
Result of research: This spin-off came from the CompMusic research project directed by Xavier Serra	
To generate	**The academic culture**: They are doing academic and applied research on infotainment and music education. **The internal identification**: They identify potential ideas on music learning assessment.
Business idea: They developed Riyaz as a flagship product.	
To finalize	**Protection of ideas:** The University owned the technology when they were working on CompMusic but was transferred to the spin-off in its creation. **The development of business ideas**: The UPF provides some advise trough the innovation department. **Financing:** The UPF didn't bring the financing.
New venture project: MusicMuni Labs was founded recently, so they only have the Riyaz product which is an app to assess singing.	
To launch	**Access to resources**: The University brings human resources and research support through the MTG. **Relationships with the university of origin**: The University promotes the spin-off in music technology presentations, meetings and conferences. Also it's a business partner of the MusicMuni Labs..
Spin-off firm: This is a very young spin-off so they rely on the researches and Riyaz	
To strengthen	**The relocation risk**: Is the only spin-off not located in Barcelona but in Bengaluru, India. This is because they are aiming carnatic and hindustanic singing. **The change of trajectories**:In the future they want to focus on application developments for singing courses
Economic Value: They are a small team of 8 people, but they have very specific roles from technological to business management.	

5. Conclusions

We established a correlation between the factors proposed in the stage model by F.N. Ndonzuau et. al. and the archetypes proposed by Jean-Jaques Degroof et. al. to obtain a set of results that identifyes the key factors that affects to the Music Technology Group's spin-offs of the UPF, providing an explanation of the factors that made some of them succesful and the factors that affected in the fail of one of them. This case study exposes a clear understanding about how is the current situation of these companies and analyzes the processes and stages that these companies face during their creation and growth.

The results of this work are very specific, containing information only about the MTG spin-offs. There are lot of variables that could affect the success or failure of this type of spin-offs as the location of the university, the entrepreneurial structure and culture, the type of industry, etc, for these reason we can't generalise to every academic

spin-off in music technology, but the information, the analyzed methodology and the conclusions could be perfectly applied in other universities and industries.

Also, in this paper is only taken into account the researchers point of view. For relevant future work it will be interesting to perform an extension of this research including interviews with the UPF's innovation department, to have a more precise state of the policies on technology transfer, licensing and spin-offs. This work also could be extended to the local innovation Institutions, such as Barcelona Activa and Acció, to identify and analyze their policies and the resources that they can offer to start-up projects.

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APPENDIX A: Questionnaire.

Stage 1: There was an idea..

- The initial idea, where it came from? Who proposed it? Was it the result of a research paper, a collective work or a thesis? When it happened?
- At the moment of the initial idea, how was the university promoting entrepreneurial projects? Do you think that there were a clearly preference for research meant to increase knowledge than to practical applications?
- How the university assessed the initial idea? Which kind of resources did you have back from them? Which one the university brought to you?

Stage 2: The idea was identified as having business potential.

- How was decided that the initial idea had business potential? It occurred before or after the test of the idea? What kind of resources did you receive from the university at this point?
- There was university personnel dedicated to the legal protection of the intellectual property when you started to focus the idea into a business approach? Who owned the intellectual property, the university or the researchers?
- There was any other company, institution or investor that gave additional resources (human, legal, economic) to you? What were the conditions?
- Were there any other potential business ideas at that moment? Do you consider that the selection process of your idea was exhaustive?
- Who made the market study to decide the launching of the new venture?

Stage 3: The idea now becomes a business venture...

- How many people were involved in the spin-off venture's team when it started? Which role they played?
- Nowadays, how many people are working in the spin-off and which type of role are them playing? Do you have personnel dedicated only in business development area?
- Has the university personnel dedicated to advise the spin-off? What is the role in the university now that the spin-off is working?
- Did you rely in any other activity than the development of the initial idea, incomes increase, e.g. consulting?
- Did the spin off make technology transfer? With whom? Under which conditions?
- How do you consider the spin off impacted in the music industry? Reached it local, national or international market?

- How do you advertise your spin-off? Do you participate in any scientific network? Is it that network local, national or international?

- Do you consider that the UPF is located in a place with weak entrepreneurial structure (@22 district in Barcelona)? (e.g. in comparison with Silicon Valley which is one of the biggest tech cluster in the world.)

- Would you like to add something?

Best practices in Industry-University collaboration within the biomedical sector in the US: a review of two successful cases

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Abstract. For research to contribute to addressing major issues we face as a society, collaborations between researchers and practitioners have increasingly been seen as essential. In recent years, University-Industry (UI) collaboration has been beneficial not only to the collaborators, but has resulted in novel technologies and tools that have enhanced society and daily life. Although there is a growing body of research on collaborations there are some key practical issues about such collaborations which, due to the little attention they have received, make success a hit-or-miss. In this study, we analyze two specific cases and how they addressed key management issues to characterize which practices are most likely to result in a successful collaboration. We focus on examples drawn from the biomedical sector in the United States and conclude what should be taken into account by the parties involved in a partnership.

Keywords: University-Industry Collaboration · Successful Partnership · Best practices · Biomedical Sector · Healthcare · Management issues

1 Introduction

Over the last decades, the relationship between industry and universities has changed significantly in the US, and in certain sectors of research, like biomedical, heavily intensified. In the mid 20s, collaborations were mainly focused on finding applications in private industry for research innovations. Meanwhile, in the 60s there was an increase in the importance of intellectual property and patenting, which culminated with the Bayh-Dole Act passed by Congress in 1980. There, it was stated that inventions resulting from federal or private funding could be owned by a university, business or non-profit institution [13]. This represented a formalization by the US government between academia and industry as it legislated patents and licenses for products developed by faculty members and researchers [6]. The act had lasting effects because it regulated intellectual property, thus making collaborations more desirable to researchers by alleviating some of the pressure external funding imposed on them, be it governmental or from the private industry. In recent years, the funds provided by

the US government for in research in the biomedical sector have increased [4]. Figure 1 shows the expenditures in Health Research in the US between 2013 and 2016, highlighting the increase in the expenditures from industry ($92.970M to 115.862M) and universities ($7.149M to 8.604M)

In the beginning of the 2000s, researchers from Stanford University Center for Biomedical Ethics carried out a cross-sectional survey and content analysis of more than 89 US institutions with funding from the National Institutes of Health showing a wide variation in the management of conflicts of interest which had led to severe misunderstandings of the objectives between researchers and industry [8]. There are many issues to be addressed between both parties if the experience is beneficial to both, and the focus of this paper is on the ones we consider as key issues that hinder positive relationships [11]. In a general context, there are three key management issues to be addressed by any university-industry collaboration, which we analyze in section 2. More specifically, focusing on the biomedical sector, as highlighted by several papers in reputed medical journals there exist key conflicts of interest between investigators, institutions and patients [6,10,9]. In section 3 , we aim to analyze two successful cases of industry-university collaboration: the University of Tennessee (UT) and Siemens, and the University of Maryland (UMD) and Waters Corporation [1]. Furthermore, in section 4 our objective is to highlight some of the main aspects that resulted in a successful collaboration in both of these cases. With all of this in mind, we may be able to point out a general framework to advice on a fruitful relationship in University-Industry collaboration.

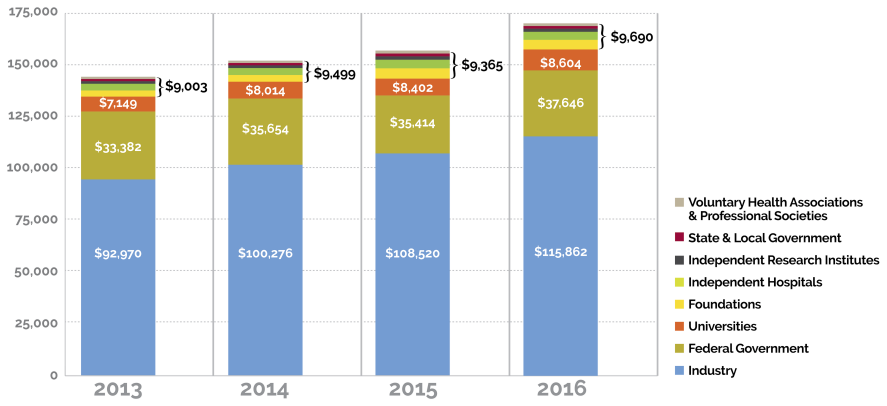

Fig. 1. Estimated U.S. Medical and Health Research Expenditures in millions of dollars. From [4]

2 Key Management Issues

As pointed out by Bammer [7], the starting point in analyzing the management of successful practices is for the parties involved to effectively harness their differences. Most reasons to embark on a collaboration of this kind have a key similarity: the point of working with someone else is to draw together partners with diverse attributes relevant to the research problem at hand. Thus, the first issue is to acknowledge the strengths that each party provides.

To continue with, the next issue is which relevant differences to include in a research collaboration. It is impossible for a research project to consider everything that may possibly be relevant because the current problems being addressed by research involve a complex web of interconnections. Variations in ideas, interests and personality will provide potential sources of unproductive conflict. Being so, it is imperative to determine what will be included and excluded in any particular research collaboration.

Furthermore, the second issue may raise questions of legitimacy and authorization, which leads to the third key management issue. Research which addresses complex problems and which aims to involve a diverse group of researchers with different specialties, as well as various stakeholders often requires a range of inter-institutional agreements. Thus, deciding on who gets the rights of usage, patents, data, funds, outputs and intellectual property is to be well established for a positive result.

On the problem of measuring whether a research collaboration is successful or not, multiple dimensions must be taken into account. For projects aiming at a product, at least some aspects of success are relatively easy to define and evaluate, especially on terms of whether the product was achieved on time and on budget. However, as is the case of both of our examples, when collaborations become long-term the results are composed of many factors, which we lay out in the following sections.

Our research methodology proposal for finding out the best practices for solving the mentioned key management issues is to analyze both collaborations in terms of the type of engagement, duration, budget, government participation and final outcomes.

3 Successful collaborations: two examples of good practices

Prior to the analysis of the two above mentioned collaborations, we will explain our choice of these collaborations for this study.

The biomedical field is currently evolving and improving in ways different than ever before. Nowadays, medicine is improving mainly because of its coupling with advanced technologies. However, when cutting-edge technology is to be used, there is a need of collecting new resources which include experts on the field and top-quality equipment. This may influence different institutions to try to find collaborations with new partners whose goals may substantially differ

from theirs. Thus, in choosing this sector of research, we aimed at analyzing one where there is no general knowledge of how to maximize the probabilities of success. In doing so, we hope to provide a general guideline for both researchers and practitioners (be it private industry or government agencies) to develop a fruitful collaboration for all.

The choice of the specific examples was not by luck. We consider both collaborations to have been successful and to exemplify good practices. In addition, both of them have become long-term (more than five years) and are still active because the partners decided to extend their contracts due to the positive results of their joint enterprises. On why these universities chose to collaborate, the two universities involved are public universities, which generally means their budget for research is not as generous as it is for private universities of similar size. Given this relatively low budget, it is more probable that they may be interested in developing a collaboration with an outside entity, and it can be said that the motivation was similar for both. On the other hand, although both of the external parties belong to the biomedical sector, we have concluded that their motivations differed significantly. The collaboration between Waters Corporation and UMD was also mediated by the Food and Drug Administration (FDA), a governmental institution. Meanwhile, the collaboration between Siemens and UT was solely between a private company and a public institution. The influence of the government in the healthcare sector (which includes the biomedical field) is relevant because, in theory, a government has the responsibility to guarantee healthcare quality to promote wellness in its populace.

3.1 UT and Siemens

The partnership between Siemens and UT began in 2005, its main objective being the development of scintillators for medical imaging. These new scintillators would enhance the performance of devices for medical images that Siemens Medical Solutions provides hospitals with. In short, scintillators are crystalline materials that absorb radiation such as gamma and X-rays, which are normally used in nuclear medical imaging, in order to convert these into visible photons which can be transformed into electrical pulses.

Dr Chuck Melcher, a professor and researcher of the UT College of Engineering who had previously worked for Siemens Medical was the person who conceived the idea of having an academic research center capable of carrying out basic research for Siemens in a critical area for both. This idea was implemented thanks to the UT College of Engineering and senior administration from Siemens, and a contract establishing a 5 year-collaboration was signed. As outlined in their agreement, Siemens provided the UT with $500.000 per year as well as a donation of equipment valued at around $1.000.000. Meanwhile, the University supplied 185 square meters of laboratory, as well as office facilities. In addition, because of this partnership, the University of Tennessees Scintillation Materials Research Center (SMRC) was created to work for Siemens Medical Solutions.

Furthermore, research topics and financial support for graduate students and advisors was a main benefit for UT. In addition, three MSc and two PhD degrees were awarded by 2014, year by which the team had published around 40 journal articles supplemented by several patent applications and numerous conference presentations, adding to the prestige and recognizement of both Siemens and UT in the biomedical field. In fact, both parts were so pleased by the success of the collaboration that they decided to extend the contract for another 5 years (until 2015).

3.2 UMD and Waters Corporation

Signed in 2010, the alliance between the UMDs Joint Institute for Food Safety and Applied Nutrition (JIFSAN) and Waters Corporation resulted in the creation of the International Food Safety Training Laboratory (IFSTL). This partnership is committed to training professionals from around the world in the field of analytic methods for food safety in microbiology and chemistry.

JIFSAN was created in 1996 through a Collaborative Agreement between the UMD and the FDA. Its initial purpose was to provide services of research, education and outreach in the fields of food safety and applied nutrition for US practitioners. However, the FDA was faced with countless requests to train foreign professionals, which could not be done in their respective nations because of a lack of resources. Waters Corporation, a developer and manufacturer of separations and detection laboratory equipment with an excellent line of products, faced the inability to train customers on methods recommended by governments and international organizations. As stated by Waters Corporations Executive Vice President Art Caputo, the corporation learned from their customers that there was a real need for help and support in understanding the diverse food safety technologies and standards that exist around the globe [5].

Their respective shortcomings led to the need of joining efforts in order to complement each others strengths and create an alliance. JIFSAN was able to open IFSTL thanks to the financial and technical assistance from Waters Corporation. The latter funded the renovations needed to establish a training laboratory and provided it with high quality equipment. In return, the University contributed with three years rent and granted access to JIFSAN support resources for Waters Corporation.

Table 1. Summary of both partnerships.

Collaboration	**Siemens & U. Tennessee**	**Waters Corp. & U. Maryland**
Engagement level	Collaboration	Alliance
Duration	2005 - Present	2011 - Present
Budget	$500k + $1M equipment	–
Government participation	No	Non-monetary. Advisor

After almost two years from the opening of the new training facilities, the alliance led to great achievement, having trained professionals from countries including Guatemala, Peru, Mexico, the Dominican Republic, Honduras, Chile, Pakistan, China, Philippines, Indonesia and Malaysia. Feedback provided by the professionals has been positive, stating that following their training, they had improved laboratory capacity in food safety, a fact confirmed by the reduction of import alerts issued from the trainees regions. Additionally, students from the UMD were hired as teaching assistants, and a graduate student was hired as a full-time instructor. Waters Corporation benefited by the exposure it has received and is now regarded among the leading sources of equipment for the international food safety market.

Finally, as a result of the alliance, a second IFSTL was opened 16 months after the initial agreement at the Food and Environment Research Agency in the UK, and there are currently plans for additional network laboratories to be developed in China, India and Australia.

A summary of both described collaborations is shown in Table 1.

4 Discussion

Beginning with Siemens and UT it is important to bear in mind, as stated in Table 1, that the engagement is classified as a collaboration, which means both partners had their own objectives and thus benefited in different ways from their joint work [14]. On the contrary, The JIFSAN-Waters collaboration is considered to be an alliance, different from a collaboration in that it implies the two partners work together to accomplish a common goal [12].

The liaison that led to the UT-Siemens project, Dr Melcher, had previously worked for Siemens before coming to UT. Because of this common node for both partners, it was easier to develop a collaboration, as both sides felt confident with the proposed idea. On the other hand, in the JIFSAN-Waters alliance the FDA already had a close relation with UMD (through JIFSAN) and thus the FDA acted as the liaison between UMD and Waters Corporation in the search of a company that could serve the international demand they faced. It is not clear in the literature which institution came up with the idea of the alliance, but the motivation was mutual and had a common objective.

For both enterprises, success in the early stages was largely due to a clear acknowledgement of the attributes each party provided, while keeping in mind their differences, solving the first and second management issues described in section 2. For UT and Siemens, it was clear that Siemens was capable of providing the project with funding and equipment, while UT had experienced researchers in the field. In the case of JIFSAN and Waters, it was clear from the beginning that JIFSAN had knowledge for training professionals, but lacked the equipment and funding for fulfilling the international requests from customers. Waters Corporation had high quality equipment and funds, but did not have the knowledge for carrying out effective training courses. Thus, in both cases both parties knew

exactly what was needed from each other, so their differences could easily be harnessed from the beginning, establishing a collaborative synergy.

Furthermore, members from Siemens and UT planned their strategy in order to avoid misunderstandings in defining what content was suitable for publication or to patent and which institution should take advantage of it. They had weekly face-to-face meetings where they reported the work carried out and decide which of these belonged to each one. Regarding issues on legitimacy, benefits and intellectual rights, these matters were managed properly by the JIFSAN-Waters alliance. Though it was easier because although the alliance led to the creation of a new institute, no products or inventions resulted from it, so no patents were created in the process [8].

Regarding the duration of the engagements, both of them are still active today. The positive results of both relationships has yielded strong ties between the pairs of institutions that have opened new paths that were not foreseeable when the collaborations started.

Since its foundation, the SMRC has expanded to other areas such as homeland security inspection and monitoring, but medical imaging continues to be the core research of the SMRC [3]. The most remarkable result is that the center carries on working for Siemens Medical, and that what started as a university-industry collaboration became a research center that is now considered among the world leaders in scintillation discovery, crystal growth, and material characterization thanks to the the efforts of members of academia supported by private funding [2].

For JIFSAN, the alliance allowed them to create an institution able to provide all the internationally requested training, covering an unexploited market demand. IFSTL would be able to start with Waters Corporations funding, and after a period of time, it would be expected to maintain itself with their own earnings. Further benefits would be of interest for the U.S. government, since they would receive funds from other countries and would be regarded as having the highest standards for food safety and applied nutrition in the world. For Waters Corporation, an increasing number of professionals trained using their advanced techniques and high quality equipment would mean an increase in their international exposure and also in the demand of their products.

5 Conclusion

We have analyzed the outcomes of two different collaborations between universities and industry in the US biomedical sector. The aim of this paper was to shed light on the best practices in this sector between universities and companies in order to advice future efforts of collaboration.

Early communication plays a key role in any successful collaboration. As commented in section 4, it is highly advisable to have periodic meetings where both parties are updated on the evolution of the research, new findings, possible patents, data, intellectual property, etc. This will make it more likely that the shared objectives are met and exploited. In the case that the outcomes are not

as desired, flexibility and the ability to adapt to changing circumstances will prevent negative results.

Moreover, the government's lack of involvement in the UT-Siemens collaboration was not a barrier to its success. On the other hand, the US government's advice during key processes of the Waters-UMD alliance can be argued to have been crucial in its success. Thus, when given the option to include the government in a joint effort, our advice is to do so only if it will improve the chances of success. A proposed further research topic could be cases where the government played a detrimental role in the success of a collaboration.

It is also clearly advisable to 'divide and conquer' in order to exploit the attributes that each party can offer. This can be done by assessing the weaknesses of each party with the strengths of the other. And as mentioned before, in the case of shortcomings, it is essential to be flexible on the agenda of the project, and change the scope of the efforts if need be.

Furthermore, these two cases prove the benefits of aiming for long-term strategic collaborations [15]. This enhances synergy between parties and also gives more time to correctly define the terms, goals and limitations for each side, thus making the joint effort more desirable for both. Another proposed further research topic is a case study on negative collaborations with the duration of the initial contract in mind.

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What are the challenges students may face during the PhD process?

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Abstract. Universally, the literature on the challenges students may face during the PhD process has increased. However, just few of it considers the most common challenges. Most of the literature focuses in one challenge such as proposal, supervision, etc. In a recent systematic review of research, published in English- language literature was investigated. From the 18 information sources that met the study's criteria, this review examined the presence of the most important challenges during the PhD process. Information was mainly gathered from books and journal papers. Fewer information was collected from web pages. This study confirmed that the most common challenges students face during the PhD process are proposal, supervision, research skills, emotional and next steps.

Keywords: PhD · Challenges · Proposal · Supervision · Research Skills · Emotional · Next Steps.

1 Introduction

Research on the challenges students may face during their PhD has been present since this academic degree was introduced during the 19th century. However, usually this research tends to focus only in one challenge such as proposal, supervision, etc. In a recent systematic review of research, published in English-language literature was investigated. This paper focuses on the most common challenges during the PhD process and reviews them in detail. The aim of this paper is to help students to understand the different PhD stages and challenges by giving them good and beneficial sources to look at. In this way, we expect them to have a brighter PhD journey. We don't expect to develop a step- by-

step guide on how to deal with these challenges, because the variety of PhDs and the complexity of research mean that no set process can ever adequately cover every possible eventuality [11].

2 Research Methodology

2.1 Search Strategy

The strategy aimed to identify and summarize literature published in English-language which presents information about the challenges students may face during the PhD process.

2.2 Search Methods

An historical method combined with a literature review was performed in this study. During October 2018 and November 2018, searches were done through various information sources such as books, journal papers, web pages, etc. Once relevant information was found, it was reviewed.

2.3 Study's criteria

Since PhD studies keep changing across the years, the study's criteria only includes information from 2004 onwards.

2.4 Data extraction and synthesis

Information sources that met the study's criteria were reviewed in detail.

3 Results

3.1 PhD Challenges

After reviewing in detail each of the information sources that met the study's criteria the analysis was able to confirm that the most common challenges students face during the PhD process are proposal, supervision, research skills, emotional and next steps. In the following sections, each of these challenges are reviewed in detail.

3.1.1 Proposal

For those who are looking and preparing for a PhD, it doesn't matter what the topic is, there is no escape from writing a research proposal at the beginning. There are a lot of PhDs and research topics, where some of them are dedicated for university degrees and other for research careers or just for seeking academic funding. In all cases, it is still important to write a proposal at the beginning,

in order to convince others about your topic, why it is interesting and the useful results that will provide. In addition, it is important to convince others that your topic is worthwhile [8]. Also, the research proposal is important because it is used to evaluate the critical thinking and the usage of the relevant literature [2]. Writing a research proposal can be easy but in most cases it is hard because it has a lot of aspects that should be taken into consideration like the format and the structure of the proposal, also narrowing and focusing on the topic while showing the relevant literature [2]. The challenges that appear while writing a research proposal are related to the structure of the proposal, in other words, there are different types of challenges while writing each part of the structure. The next part is showing some common structures with some details about each of them, in order to present and identify what kind of challenges could be expected [2]. Most of the universities have a specific structure or format provided to the student in order to follow this format while writing the proposal, but in general, the proposal structure or format is similar to the one shown below [2]:

- **The title:** the most challenging part is choosing a good title which provides direct indication of your project.
- **The introduction:** the most challenging aspect here is to introduce the problem and include a brief background.
- **The research question:** it is the main question addressed in the proposal. It may also include the hypothesis.
- **The aim of the research:** these are the goals and outcomes that will be achieved, also the contribution.
- **Literature review:** it is one of the most difficult parts, which summarizes the related studies to the proposal research that have been done before, also initiates the arguments which will support the needs of the research proposal. In addition, the literature review part should focus on the most relevant publications related to the proposed research.
- **Methodology:** in this section it is important to show the methods used to gather information and getting data, also the analysis methods. In addition, the ethical consideration and the timeline should be presented.

In all of these steps of the proposal structure, there are a lot of different challenges which have to be taken into consideration before writing the research proposal. As shown above, a lot of challenges and barriers could appear. The most fixed and common challenge is the literature review, which is considered to be a very important and difficult part and also takes a lot of time and effort to be done properly. The literature review section appears in a lot of papers and journals as one of the most challenging stages that has to be taken into account. For example, it appears in this article below as an important structure for developing a research proposal. It also appears in some other papers and journals that are related to the same topic. "*Your references should provide the reader with a good sense of your grasp on the literature and how you can contribute to it...*" [3]. There are a lot of challenges that a student may face during the process of writing the research proposal which is an important stage

in order to get a research or PhD position. Among all of these challenges, one of the most appearing challenges is the literature review. This aspect must be included carefully in the proposal.

3.1.2 Supervision

When you become a PhD student, you initiate relationship, both personally and professionally, with your supervisor. This is more intense than the previous academic relationships, because as a research student you will have much more of your supervisor's attention and time.

A good relationship between student and supervisor needs work by both sides. It isn't your supervisor's responsibility to make everything all right, it's up to both of you to work together [15].

The review of the literature related to the present study provides some information on the most relevant aspects to take into account, paying attention to how both the students and supervisors perceive this relationship and how they think it should be.

The study reveals that the students perceive the supervisor as a person that provides access to resources and organizes the work, masters and teaches research techniques, shows interest and discussed ideas, controls and plans the student's work [14]. However, supervisors perceive their role as a person that critiques the student's work supporting some of the student's decisions, provides freedom, and shows interests and discusses ideas, but also directs and provides ideas especially at the beginning [14].

Some literature suggests that the way the students and supervisors perceive the supervision role differs in some ways from what they expect. "*The Unwritten Rules of PhD Research (Open Up StudySkills)*" [15] considers that the minimum supervisory role involves filling in the relevant forms, writing annual reports and liaising with the organization where the student is doing his fieldwork; beyond that, there are other roles that include some specific technical and intellectual support, administrative support, management and personal support. However, [14] reflects that the students expect from their supervisor a person that has quality of relationships, direction and guidance skills, mastery of the field and organization. On the other hand, the supervisors believe their students expect from them a supportive attitude, a mastery of the field, direction and organization as well.

"*The Voice of PhD Candidates and PhD Supervisor*" [18] deepen into this aspects, mentioning the flexibility, the patience and empathy as the best personal skills, the ample experience and the high knowledge of the field involved as the best knowledge skills and the ability to motivate and create a safe learning environment and the quality to build a personal relationship as the best coaching skills to establish a good supervision relationship.

Apart from having good skills, a good relationship between student and supervisor needs work day by day, demonstrating all these skills constantly, in order to increase their confidence and have a stronger collaboration. Students

and supervisors should also be sensitive to each other's needs and ways of working and should communicate these issues with each other as and when required [9].

The book "*The Unwritten Rules of PhD Research (Open Up StudySkills)*" [15] discusses these topics in a very detailed way, focusing on how to communicate each other in a clear and understandable way. In this sense, they propose several aspects to take into account for doing an effective supervision meeting. They consider that a student should send a discussion document to the supervisor before the meeting, provide key publications, show up on time, write down in a clear way his objectives, check the agenda with the supervisor, behave well, take notes, book the next meeting and after the meeting, write a list of agreed action items (with deadlines if possible), and email it to all concerned.

As you can observe, the supervision challenge is a relevant aspect of all the PhD process that could define the success in reaching the objectives of your PhD research and your future job expectations. Actually, Youngdi Zhou, a cognitive neuroscientist at the East China Normal University in Shanghai, identifies the length of the PhD training, the control of the quality and the mechanism of supervision process as one of the main problems of the low quality of many graduates. [7]. Consistent with this view, Mounir Nana, a food scientist and PhD supervisor at Minia University, says "*The PhD student in Egypt faces numerous problems; unfortunately, many supervisors do not bother, and end up adding one more hurdle in the student's way...*" [7].

3.1.3 Research Skills

	Writing			
	Basic Skills	***%***	***Advanced skills***	***%***
1.	#To be able to start writing the literature review (79%).	79	1. *To be able to write in a convincing way (93%).	93
2.	#Don't know how to write down ideas (54.3%).	54.3	2. *To be able to relate the literature review to my topic of research (79%).	79
3.	#Don't know how to connect the ideas (44.3%).	44.3	3. *Don't know how to write critically (50%).	50
4.	#Don't know how to use transitions to show coherence (40%).	40	4. *Don't know how to synthesise (41.4%).	41.4
5.	#Don't know how to extract main ideas (35.7%).	35.7	5. *Don't know how to review (40%).	40
6.	#Don't know how to summarise (28.6%).	28.6	6. *Don't know how to paraphrase (40%).	40
7.	#Don't know how to start a paragraph (27.1).	27.1	7. *Don't know how to project argument (21.4%).	21.4
8.	#Don't know where to start writing (25.7%).	25.7	8. *Don't know when to stop writing 20%).	20
9.	#Don't know how to organise writing (21.5).	21.5	9. *Don't know how to write academically (20%).	20
10.	#Don't know when to start writing (20%).	20	10. *Don't know how to give my own voice in the writing (15.7%).	15.7
11.	#Don't know how to define concepts (4.3%).	4.3	11. *Don't know where to limit myself when reading and writing (14.3%).	14.3
			12. *Don't know how to get support for review (7.1%).	7.1
			13. *Don't know how to be precise in writing (7.1%).	7.1
			14. Don't know how to be clear in writing (4.3%).	4.3

Fig. 1. Basic and Advanced Skills in Writing [5].

Postgraduate students face many difficulties in writing their thesis. They need to have the reading and writing skills to ensure that they can proceed with their postgraduate studies and complete them on time [5]. For instance, [16] shows the importance of these skills by field.

During a PhD, students have to read a lot and this is the first thing they will do starting their PhD thesis. It needs to be in the right way because this part overlaps with the writing part so that if they also have an expert knowledge about the writing section, then they will use what they read in a better way [6]. For example, this reading stage is discussed in a very detailed way in [6], but some of reading habits that assist the reading are:

- Regular reading time per day.
- Reading books and papers.
- Sense of completeness for the subject you are reading.
- Reading papers with full citations.
- Read chapter before you sleep even if you are tired.
- Take notes from conferences.
- Filter your reading to increase the interest level of what you choose by using your network,
- Find a reading buddy.

Postgraduate students, may be able to read and understand complex topics, but they may find it difficult to write in the same level as their reading. However, some books such as [6] and [10] show how to discover the conventions of structure, organization, grammar and vocabulary for writing in an specific field and provide with the tools to write in a professional way, then having decent presentations and viva. If we look at some people skills, [5] shows a table of writing difficulties in doing a literature review for seventy postgraduate students from nine faculties in one public university in the Klang Valley. For instance, **Fig. 1.** shows that most of participants have a lot of problems in the advanced writing skills.

3.1.4 Emotional

Facing a PhD thesis could be an arduous task which requires hard working and dedication. Usually, requires the candidate to undertake a lengthy period of independent research which will culminate in the production of a thesis based on their work. This means constant pressure to achieve the objective that can become overwhelming, exhausting or in a crisis, therefore, it is really important to manage accurately the stress [13].

Concretely, during the PhD process, positive emotions (including elation and enthusiasm) seems to dominate initially, but, also some anxiety could come out. The negative emotions in the middle stage are often associated with the realization of the size of the project and the amount of time and effort it will require. Finally, the end stage of the PhD is also characterized by a mix of strongly felt negative and positive emotions. Negative emotions could include fear, frustration, anxiety, boredom, and panic; while positive emotions included elation and satisfaction [12].

In extreme cases, the emotions felt during this process can become mental problems (for instance, a crisis or an anxiety attack). Therefore, the objective is to try to detect the symptom, as soon as possible, and try to find some tools to avoid these extreme situations. But, it is important to notice, each person requires a unique solution. This it is a really important task because, the literature review shows that the stress it is more frequent than never [4], due to, the research conditions in universities.

On the other hand, the mental health of the student affects the quality of the PhD work. And of course, effects the relationship with both their co- workers and the supervisor [9].

In fact, according to the literature, if the students cannot find an appropriate technique for emotional management, they will, finally, withdraw their candidature. But for others, the time required to complete their research will extend more than it was originally planned [12] [17].

Parallel to all of this, and what probably allows the student to be successful, is the ability to ask for help when truly needed.

3.1.5 Next Steps

Depending on the field of the PhD and the process done to achieve it, the last step is the possible professional outcomes. It is important to notice that, the number of owners of a PhD going into the industry is growing closer to those who are going into academic positions; nowadays, there is more offer than ever. And one of the reasons for this trend is, the average salary in the industry is more than 40% higher than in academic [1].

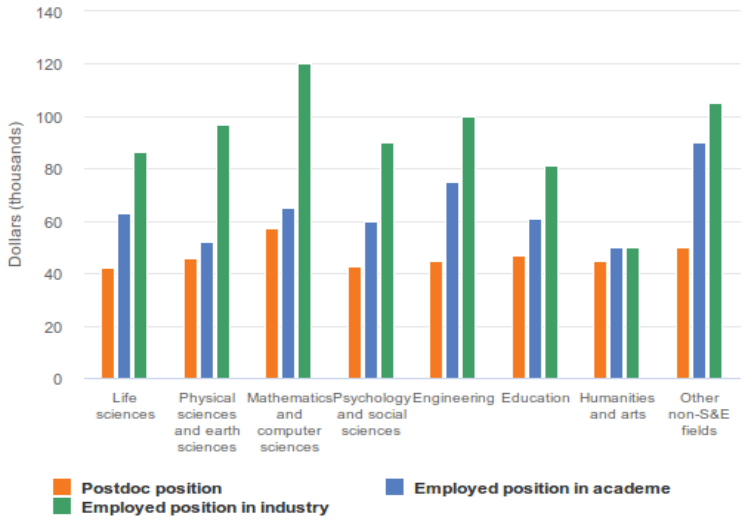

Fig. 2. Median basic salary of U.S. doctorate recipients with definite commitments in the United States, by position type and broad field of study: 2015 [1].

Next follows a list of the main possible post- PhD career opportunities:

- **Academic:** post- doctorate, research assistant or professor. Post- doctorate and research assistants are one way to continue is research after completion of their PhD.
- **Professional:** a well- recognized position in your sector/field. Or not related to the PhD, because the skills learned will be useful.

- **Research, development, consultancy:** research, design and strategy decisions, both possible in the public or private industry.
- **Start-Up:** possibility to take a research project and develop it into a private environment.

4 Conclusion

This study described a structured literature review, and explored the most common challenges students may face during the PhD process. We confirmed the most relevant challenges are the proposal, supervision, research skills, emotional and next steps. As mentioned before, the aim of this paper is to help students to understand the different PhD stages and challenges by giving them good and beneficial sources to look at. In this way, we expect them to have a brighter PhD journey. In the other hand, we expect this paper would lead future work to focus on future careers after obtaining the PhD academic degree.

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A meta-study on PhD programs attrition causes

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Abstract. The attrition rates of PhD programs have increased in the last 15 years quite dramatically, arriving to between 40-50% in some cases. As PhD programs take many years and a large amount of financial support to complete, it seems like an important issue to address. This paper reviews previous studies done in this area and presents the main causes with the aim of combining them into a single approach to face attrition from advanced academic programs. This paper also studies some relevant data related to these main ideas in order to provide a global view of the situation. Finally, a general viewpoint is proposed.

Keywords: PhD program, Attrition rates, PhD life, PhD difficulties, Mental health, Academia

1 Introduction

A PhD program takes many years and a considerable amount of financial support to complete, so it is worrying that anywhere between 40-50% [1] of PhD candidates drop out before completion. It is in no one's interest for PhD students to drop out before completion. In this case, the student will have lost anywhere from a few months to a years of their life, the supervisor will have spent much of their precious research time on projects that have gone nowhere and the university has lost the money they used to fund the student for the duration of their studies. More abstractly, one could argue that society in general has lost a potential research breakthrough. This study wishes to investigate the reasons for the high attrition rate and ways to lower it.

In Figure 1, we have plotted the most recent data from the PhD Completion Project [2], which shows that PhD dropout rates have increased over a ten year period. From this, one can argue that this research is incredibly relevant right now.

In our opinion, the most important limitation when addressing papers directly studying doctoral attrition, is the lack of an integrated theory about drop out causes. We found that some studies in our review were lacking in depth and therefore were unable to form proper explanatory arguments.

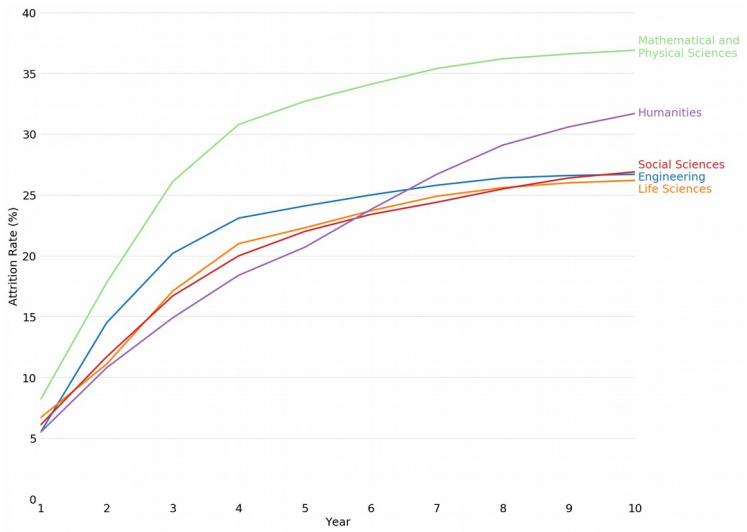

Figure 1. A plot of attrition rates of PhD programs over a recent 10 year period.

[3] states that the criteria distinguishing students who complete their PhD and those who do not is the feeling of making progress in a project that makes sense to them without causing too much stress. However, this argument is too general to contain information detailed enough to give a sensible explanation of dropout.

[4] had many findings on the factors of doctoral drop out, however those findings seemed logically scattered and did not form an integrated structure.

Furthermore, there is a lot of useful literature on mental health, financial difficulties and doctoral academic factors that is related to the topic addressed, but not used in the drop out studies.

Based on this analysis of state-of-the-art, we argue that a well-structured systemic and explanatory theory is needed to address the high attrition rate. This paper aims to propose such a theory by extracting the main findings of the literature.

After our analysis of existing literature, we propose a categorization to classify all possible causes into three aspects: financial state, mental health & wellbeing and academic factors.

The rest of the paper is organized in the following manner. First, we introduce the research methodology used through this study. Secondly, in the results section we present our findings and propose our theory organized by the three aspects mentioned above. Finally, the conclusions of the paper are presented.

2 Research methodology

This project is based on a literature review methodology. The main interests are studies on different approaches to identify causes related with PhD attrition rates, or ones addressing specific problems. To do so, we searched for the terms “PhD dropout”, “PhD completion” and “PhD wellbeing” in Google Scholar and UPFinder. After reviewing the results, the most relevant papers where selected to be used as the main sources. The papers selected as relevant were the ones that discussed the reasons for dropouts. In reading these, other interesting sources were found in their references, including not directly related papers.

With the intention of complimenting the information from the selected studies, other information was gathered from different sources like, newspapers, university websites, blogs as well as research and governmental organisations from around the world.

3 Results

3.1 Financial security

In this section, we will look at the financial situation of phd students, and how it may affect the dropout rate. The reason we are looking at financial situation is that it is one of the concerns of PhD students, with some saying that scholarships for students “are often really small”. This may be due to a number of reasons, one such theory is that there may be “too many PhD students in relation to available financing”[5].

We will now look at a case study of three universities; the University of Edinburgh (UoE), Imperial College London (ICL) and New York University (NYU). All the data on cost of living (COL) was collected from each universities website [6], [7], [8], on specific pages about cost of living in the respective cities, where as the average salary in each university was found on Glassdoor [9], [10], [11]. This information is shown in table 2.

Table 2. Average Cost of living, salary and disposable income of three different universities

University	COL	Salary	Disposable Income
UoE	£12,390 (€13,986)	£14,000 (€15,804)	£1,610 (€1,817)
ICL	£15,000 (€16,933)	£16,573 (€18,708)	£1,573 (€1,776)
NYU	$27,683 (€24,270)	$30,000 (€26,301)	$2,317 (€2,031)

From the above table, we can see a few things. First, the disposable income of PhD students seems fairly consistent, at least in our three examples. For instance, students at UoE have roughly the same amount of money left over as those at ICL. Secondly, the disposable income of these students isn't significant, especially considering that the COL calculations used by the universities only take into consideration the bare necessities, such as food, rent, utilities, etc. It fails to take into account savings and debt. Students from some countries in particular will be straddled with student debt which they will have to pay off. For instance, students graduating from England leave university with an average debt of £32,220 (€28,247), whilst in America, it is an average of $34,000 (€29,807) [12], and this will have to be paid off during the course of the PhD program.

Another factor that may affect students generally is lack of financial security. A recent study found that four out of 10 adults in the UK have less than £500 (€438) in their savings [13], many of these people tend to be low earners, such as PhD students. This lack of financial security has well known links to mental health [14], and so a lack of financial security will affect either the quality of work produced by the student or, in the worst case scenario, cause the student to drop out. Both cases could ideally be avoided by giving assistance to students in some form.

One thing that is worth pointing out is the hours worked during a PhD against the hours they would be funded for. Many PhD students work as many as 70 hours a week out of necessity [15], but are only paid for the hours they are expected to work, usually eight hours a day. This may be because many scholarships are time limited, so the student may feel pressured to work longer hours, or may just be because the student is personally invested in the project and is happy to work the extra hours for it. In either case, it is only fair that a student is compensated for their work, and so this must be addressed, but more importantly, long working hours have an adverse effect on mental health [16], which could lead to a decrease in the students performance.

In order to combat these challenges, we make a few recommendations. The first is to increase the average grant or scholarship awarded to students. This is obviously the most difficult financially, but offers very obvious benefits in terms of the students financial security and resulting well-being. The second is for universities to offer programmes that offer students financial support when needed. This has the benefit of being more financially viable, as the university is only contributing financial support when it is desperately needed. Finally, the working hours of students should be addressed, either by compensating students for hours worked overtime or by encouraging students to have healthier work-life balances.

3.2 Mental health and wellbeing

Another aspect to take into account when talking about attrition from PhD programs is the well-being of the candidates and their mental health. This topic is covered by some studies but not much of them relate this to the previous topics. From these studies there are some conclusions quite alarming. For instance, a study from the University of California states that "36% of doctoral respondents who had advanced to candidacy reported symptoms of depression" [17]. Another study done with

students from universities in France found that PhD students are at “risk of chronic stress, anxiety, burnout and depression” [18] . Golde in 2000 stated that “although the occasional student commits suicide or murder” there is not much focus on why students leave because the main focus of universities is in helping the successful ones [19]. Fortunately it seems that this tendency has reverted in the last few years, and attention to this issue has increased. Several authors conclude direct links between mental distress and withdrawal from academia [20], [5] ,[18].

When talking about mental health, one of the main reasons for attrition is emotional exhaustion. This can lead to feelings of psychological and emotional drainage, and can even lead to physical fatigue. Several reasons can induce this emotional tiredness, some of them being related to the influence of the environment [5] . Feedback from the supervisor and other colleagues of the academic community is an important factor contributing to emotions and to the feeling of empowerment. However, “career training and prospects, research experience” and “the impact” in society of the thesis topic have a higher influence [18]. Stress and anxiety are also important factors negatively related to study engagement. Problems with time management, workload, evaluation, competition and pressure to be part of an academic institution (like pressure to publish), can influence negatively towards these feelings. Moreover, all these issues tend to lead to depression.

Mental health and wellbeing is not only an important factor for the academic community, mental disorders are big challenge for the public health systems, as these affect “at least one in four people at some time in their lives” [21]. Another factor to take into account when talking about these issues is the stigma there is in society when addressing this points. This stigma, “affects people’s self-esteem” and difficult their social abilities and capacities for study or work [22] .

In Europe two main organisations started focusing in addressing mental health and wellbeing: The World Health Organisation, regional office for Europe created the Mental Health Action Plan for Europe in 2005 and the European Commission formed the European Pact for Mental Health and Well-being in 2008 [23]. These two associations have created several guidelines for country governments, public institutions (including education) and businesses to follow. Some of the main ideas in these general actions plans converge with the studies about Ph.D. attrition rate.

Experts suggest that the main action should be preventive interventions. Prevention programs for depression disorders are feasible and effective [24]. These have been proven to reduce the risk of developing depression disorders up to a 35% in working population [25]. Some preventive interventions proposed such as having surveys filled by students [18]. If these were to be filled in regular periods, wellbeing agents from universities could have a proper evaluation on students health. Also, relatively simple low-cost interventions have been proved to be effective [25]. An example from “Preventing Depression In the WHO European Region” [25] is keeping contact between employers and supervisors via phone calls while on sick leave. This was shown to improve the sense of belonging and led to a reduction in the number of sick leave days.

In the academic environment it is clear as well that there is an increase in efforts to work on the wellbeing of students (and staff) to avoid mental disorders. For instance, in the United Kingdom there is an inter-universities organization called Universities UK. This organization has a board of specialists from universities around the country

to develop policies for universities to improve their services. There is a similar organisation in Australia called Enhancing Student Wellbeing, this one is exclusively focused in giving resources for university educators to deal with students wellbeing. Also, it is becoming more common to find mental health and wellbeing services in universities where students can address themselves in seek of help and advise. Maybe, though, proactive and preventative interventions should be a matter of improvement, as reports and actions plans suggest.

3.3 Academic factors

Academic factors refer to factors that directly influence the content of academic research. These factors directly determine the students' academically competent, academic progress and the quality of academic output, therefore they are key factors of the PhD dropout rate.

The academic factors related to PhD drouout can be categorized into oneself, the tutor and the faculty or department. Personal factors include their research competency, whether the project is meaningful to them, and whether the research progress direction is reasonable [3].

The importance role the research competency plays in PhD persistence is justified by rich literature, [3] states that whether students are making progress in research is a key indicator that distinguishes between the completers and the incompleters. [1] and [26] used the Self-determination Theory (SDT) model to analyze the factors of doctoral dropout, pointing out that competence is the cornerstone of doctoral students' persistence. [26] use the academic indicators such as "I can't work as fast as other doctors in our group" and "I often doubt the quality of my work" to measure the competency of doctoral students.

Albeit the justification of the importance of competency, most of the existing research doesn't reach further than general mastery and efficiency [26]. There is little systematic and in-depth discussion about which specific academic abilities distinguish winners from losers. Another related finding is that academic predictors before a Ph.D process such as a GRE score don't distinguish between the Ph.D completers and non-completers, implying that completing a PhD requires some special skills. [27] uses the model of threshold concepts to account for the hidden knowledge and skills one has to acquire when entering a new area. Without the master of the threshold concepts, learners cannot master this field. In [28], for PhD students, the threshold concepts of learning to become a researcher are mentioned, including the formation of a coherent argument/dissertation, generation a theory or model, locating or constraining the scope of the research, knowledge creation, analysis abilities and academic paradigm. If these threshold concepts are not mastered, they will be stuck, suggesting that they would fail. However, this article does not directly link the threshold concepts to the completion of the PhD.

In addition to ability, not being able to carry out research by the student's will is also related to an increase in the dropout rate. This is mainly due to supervisors attempting to control the work of the students rather than the to support their autonomy, which is one of the three main aspects contributing to a student's motivation according to SDT [26]. As mentioned in [26], autonomy rather than

controlled motivation predicts a better sense of competence, and metrics such as "I can influence the development of the paper" and "I rarely have the opportunity to make choices" are used to measure students' autonomy. In the survey of [3], all the candidates who completed their PhD had projects that followed their will, whereas eight of the 13 candidates who did not finish thought that the project was not meaningful or they did not enjoy it. Some of them thought the project was meaningless, and some have their own idea of a direction but are forced otherwise by the instructor.

The supervisors' academic support for doctoral students is the most important external source. This academic support includes research skills training/coaching, the providing of knowledge, information and academic resources. They are often considered to be the most important factor (but oneself) related to the Ph.D dropout rate. [29], [4] ,[30], [31], all pointed out that the relationship between tutor and student is crucial.

In the existing research, some papers based on the SDT model, such as [26], confirm that the academic support of the tutor to the students can reduce the student's dropout intentions, referring metrics such as "the supervisor teaches me the technical knowledge and skills needed" and "give me constructive feedback on my work". However, these papers only talk about the emphasis and efforts of the instructors on providing academic support. They do not discuss the specific academic knowledge, skills or information that the tutor can provide to support the doctoral students, thus enhancing their academic competence and thus reducing the students' Dropout rate. As far as we know, only [32] and [33] of the existing research have addressed this issue. [32] To discuss the academic support of the instructors for doctoral students from the perspective of the concept threshold, it is pointed out that the instructors should focus on training students to grasp the thresholds of ideas that they need to master in their research careers. [33] proposed the application of the cube model to the doctoral education of pediatrics to improve students' research skills. The cube model used in the paper includes research design, data analysis, communication and publishing, interdisciplinary teamwork, and research results.

The impact of staff and departments on the dropout of doctoral students is relatively small. Due to space limitations, we will not discuss them here.

4 Conclusions

We have reviewed the existing literature directly on dropout and indirectly on other closely related issues and we proposed categorizing the possible causes into three aspects: financial state, mental health & wellbeing and academic factors. After analysing these categories we suggest that these three aspects should be unified into a systematic theory instead of treating them as separate causes.

For each reason, we have collected sources of information that discuss the problems and have identified some possible solutions.

With regards to financial security, we have collected data and presented a case study of PhD students finances in three universities and discussed some of the

difficulties related to them. We have then proposed that universities can increase the grants or offer special financial support to students in need.

With regards to mental health and wellbeing we discussed the high rates of students experiencing anxiety and depression and also discussed how it is recommended to do preventative interventions.

Finally, when looking at the academic environment of PhD programs, we discussed the self-determination theory.

When looking to lower the dropout rates of PhD programs, we recommend a multifaceted approach which takes all these factors into account.

Unfortunately, our research was limited to a literature review. Future work could include implementing our suggestions as part of an empirical research experiment and examining the results over the course of a PhD students cycle. Further work could also include refining the theory have put forward.

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