A Grey Literature Review on the Impacts of Covid-19 in Software Development

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Abstract: The workplace has been changed by Covid-19. But what is the meaning of the "work from home" phenomenon in software development? This paper aims to investigate the "work from home" pandemic phenomenon in software development. Between October 2019 and December 2021, the Grey Literature review was carried out to investigate 25,251 records, collected through a scraper written in python language. Descriptive analysis was performed using data science and artificial intelligence techniques. We developed a methodology to optimize the collection and extraction of insights from the Grey Literature and reveal perceptions or cognitive distances from the social representation of the impacts of Covid-19 in software development. The main contributions of this paper are to show how Grey Literature may contribute to anticipate findings, reveal changes in the discourse regarding the effects of the pandemic on the work model, and show that in early 2021 the desire for flexibility pressed for a hybrid model. This type of literature review can assist in strategies to deal with events such as Covid-19.

1 INTRODUCTION

The Covid-19 pandemic was made official on March 11, 2020 by the World Health Organization (WHO) (Bogoch et al., 2020). Since then, studies that analyze the impacts of the pandemic in the area of Software Engineering (SE) have begun (Ralph et al., 2020; Oliveira et al., 2020). This paper aims to characterize the state-of-the-art about impacts of the pandemic on the working model of SE through a Grey Literature (GL) review (Garousi et al., 2019; Kamei et al., 2021). We also proposed the development of a methodology that optimizes the collection and extraction of insights from GL to answer the following research questions:

- RQ1: *How to automate the collection of evidences from the grey literature to investigate the impacts of Covid-19 in software development?*

- RQ2: *What are the cognitive distances in the social representation of the impacts of Covid-19 in software development?*

To answer these questions we resorted to the scientific method of Systematic Literature and Grey Literature (GL) reviews (Kitchenham and Charters, 2007; Garousi et al., 2019). Using a Python scraper algorithm we collected from Google Search Engine (GSE) the GL records for the period between October 2019 and December 2021. This process generated a corpus with 25,251 records. After the screening (Page et al., 2021) -procedures for selecting a study by relevance (Kitchenham and Charters, 2007; Garousi et al., 2019) and data extraction -procedures for answer research questions (Kitchenham and Charters, 2007; Garousi et al., 2019), data science and artificial intelligence were applied to create data synthesis -procedures for synthesizing evidence with qualitative analysis (narrative) or quantitative analysis (Kitchenham and Charters, 2007; Garousi et al., 2019), speeding up the synthesis of results. The choice to use GL resulted from the urgency of the research and the scarcity of data on the impact of pandemics in software development in the Academic or Traditional Literature, according to the guidelines for GL (Garousi et al., 2019).

The objective of RQ1 was to develop a methodological proposal that automates the process of data collection and data synthesis in GL. RQ2 aimed to reveal perceptions or cognitive distances -distance between different perceptions about an object or phenomenon (Nooteboom et al., 2007) from the social

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representation (Moscovici, 2007; Jodelet, 2001) of the impacts of Covid-19 in software development. This RQ2 is important to understand how Covid-19 (as an extreme event) can impact different aspects of software development, for example: disrupting the software development working model through "new normals".

This paper is organized as follows: Section 2 presents the background. Section 3 describes the methodology used. Section 4 reports the results. Section 5 presents the discussion and Section 6 presents the conclusions and final considerations.

2 BACKGROUND

Until recently, there were two main work models, first "work from home" and then "back to the office" (Microsoft, 2021a) (Meira, 2021). However, the effects of the pandemic were far from being binary. Now a third way has been emerging since early 2021. However, it is common knowledge that the discussion about a future of remote work is not new.

Domenico de Masi wrote back in 1993 her book called "Il telelavoro (Telework)", where the author analyzed 10 years of case studies about the challenges and benefits of telework. In 1999, in the book "The future of work", he named Chapter 17 'Working Anywhere" (de Masi, 2021). This title alone makes clear the author's vision, already at that time, that the "future of work" would be distributed or remote.

A brief review of the software engineering literature also reveals that distributed or remote is nothing new and the present authors are part of a study group that has been investigating the development of distributed software since the mid-2000s (Prikladnicki, 2003). If distributed software development, based on the very concept of remote work, has not been new for more than 20 years, how has Covid-19 really impacted SE?

Answers are coming from social representations or perceptions (Moscovici, 2007; Jodelet, 2001) of professionals in the SE value chain about the impacts of Covid-19 on the work model. Analyzing their perceptions, verifying if there are cognitive distances and what they would be, in order to arrive at a social representation of the phenomenon itself is the challenge of this paper.

Primary studies have addressed the impact of Covid19 on the productivity of software engineers, highlighting here one at the national in Brazil level (Oliveira et al., 2020) and another at the international level (Ralph et al., 2020). These were conducted through a survey online. The studies showed divergent social representations about how Covid-19 impacted the productivity of software engineers. The international study reported a loss of productivity (resulting from the lack of an adequate structure for forced remote work) and the Brazilian study reported an impact of increased productivity (resulting from fewer interruptions throughout the day). We identify in this case that there are different representations of the same phenomenon that is the very impact of Covid-19 in SE.

For Serge Moscovici and Denise Jodelet, social representations are considered a phenomenon capable of materializing the world of ideas, mobilizing the subject from the unknown to the familiar, therefore, from the abstract to the concrete (Moscovici, 2007; Jodelet, 2001). For Jodelet, social representation is related to the basic needs of apprehension and communication of/in the world, stating that we create representations out of the need to be informed about the world around us, emphasizing that they help us name and define the most different aspects of daily life, in order to interpret, make decisions and position ourselves in relation to them.

Social Representations explain how and why people give different names and concepts to the same phenomenon. For example, Domenico de Masi's telework was cited as "Flexible Working Arrangements" by the Human Resources team of UN (UN, 2019). According to The Federation of International Civil Servants Associations (FISCA) "The Future of the UN System Workforce, or the UN Future of Work, is a Task Force launched by the High-Level Committee for Management (HLCM) during its 38th Session, 15-16 October 2019". In it, flexible work arrangements (FWA) represent the modern workplace (UN, 2019).

From this point of view, the data in this GL are social representations or reported perceptions about how they understand the impacts of Covid-19 on SE. Carrying out this analysis means identifying what are the similarities, what are the trends evidenced by the reports, therefore, if there are cognitive distances or different views on the phenomenon and what they would be. What are the views on how Covid-19 impacts the SE work model? The main objective here is to answer this question. We will now describe the methods used.

3 METHOD

The Grey Literature review (GL) was performed by means of GL guidelines (Garousi et al., 2019; Kamei et al., 2020). Herewith, we defined the Search process (Section 3.1), Source selection (Section 3.2),

Study quality assessment (Section 3.3), Data extraction (Section 3.4) and Data Synthesis and Classification (Section 3.5).

3.1 Search Process

Following Kitchenham and Charters (Kitchenham and Charters, 2007) the search strings of the systematic mapping were organized in terms of population, intervention, and expected results. The comparison was omitted here because it is not relevant to the present goal. Stabilization tests were performed until the final adjustment of the search strings. The final format used was:

- Population (software engineers or software development or disaster informatics);

- Intervention (productivity or work from home or remote working);

- Result (covid impact or disaster or resilience).

As proposed by (Kitchenham and Charters, 2007), table 1 presents a summary of the search strategy adopted, the inclusion criteria (IC) and, exclusion criteria (EC) - which are described in depth in subsection 3.2.

Table 1: Data source and Search strategy.

Database	CI/CE	Search
Google Search Engine (GSE)	"Criteria" for selecting a study"	title summary key words date

The challenge in searching GL is choosing the data source. There are many alternatives. Some authors use project versioning platforms like GitHub. Others use social networks for technical support to developers such as Medium or StackOverflow. There is also the possibility to focus on newspaper news. Any choice impacts the result. To facilitate a broad spectrum search, it was chosen to use Google search results, as it can give an overview of the topic (Souza et al., 2021; de Oliveira et al., 2021).

3.2 Source Selection

For each record collected, a set of inclusion and exclusion criteria were applied. To be included, each study must meet all inclusion criteria. The Table 2 describes the inclusion criteria. Exclusion criteria, on the other hand, are described in Table 3. We excluded any study that met at least one exclusion criterion.

The study quality assessment is described below.

Table 2: Inclusion criteria list.

Code	Description
IC1	Record written in English
IC2	Record presenting empirical data, theoretical data, experience reports, or opinions;
IC3	Record published between 10/2019 and 12/2021, inclusive.
IC4	Record is available in its entirety and free of charge.
IC5	Record of blogs, tweets, annual reports, news article, presentation, videos, Q/A sites such as StackOverflow, Wiki Articles, books, magazines, government reports, white papers (Garousi et al., 2019).

Table 3: Exclusion criteria list.

Code	Description
EC1	Duplicate records.
EC2	Records not focused on Software Engineering.
EC3	Records unrelated to the Covid-19 pandemic.
EC4	Non-English language records.
EC5	Records not responding to RQ's (RQ1 and RQ2).
EC6	Records that do not explicitly address in their reports the impacts of the pandemic on SE, according to Computing Curricula 2020 - CC2020.
EC7	Records that clearly is only propaganda of professionals/companies/governments with the intention of taking advantage of the pandemic for marketing and selling a certain product or service.

3.3 Study Quality Assessment

The quality of the records of a GL is measured through the Tiers or "shades of Grey" (Garousi et al., 2019; Kamei et al., 2020). These authors state that in GL reviews it is important to minimally assess the GL quality. Tiers indicate the quality of the GL in direct relation to the font type of each record. Its analysis provides a sort of hierarchy of the possible quality of the records. The Tiers(Kamei et al., 2020) are:

- Tier-1: books/chapters, white papers, thesis, magazines and government reports;

- Tier-2: annual reports, newspaper articles, Q&A, company websites;

- Tier-3: blog, social media articles (e.g. tweets).

3.4 Data Extraction

The data extraction and mapping was performed from a Python scraper algorithm that collected from Google Search Engine (GSE) the GL records for the period between October 2019 and December 2021.

The algorithm performs a search on GSE using the search strings within a window every 24h and not limiting itself to just the first search page that displays only the first 10 page rank records, as is usually offered by private web scraping API's since most free resources are limited to delivering only the first 10 search records. This process generated a corpus with 25,251 records.

3.5 Data Synthesis and Classification

The data collected by the scraper was stored in a *.CSV table. The variables created by the scraper are:

Table 4: Classification scheme.

Variable	Description
date	date of records
header	title of records
summary	abstract of records by GSE
RQ2	Does que paper answer RQ2?

For the qualitative classification, a classification scheme was proposed by "a priori" categories for each record included in this study, namely: "Analysis of the adopted work model", "Work model issues" and "Ideal working model", based on the model adopted by the United Nations (UN, 2019). A template is available in the Appendix Section. A template is available in Appendix Section.

4 RESULTS

From an initial set of 25,251 records collected through the search process, we selected 51 records. The results are presented below.

4.1 RQ1: How to Automate the Collection of Evidence from the Gray Literature to Investigate the Impacts of Covid-19 in Software Development?

Automation was performed using a scraper to collect data from the GL using the Python programming language. The scraper made it possible to systematize

data collection (Souza et al., 2021; de Oliveira et al., 2021). The challenge in automating data collection is that each site has a unique pattern. As it was not feasible to create a scraper for each WWW site the choice was to use the Google Search Engine (GSE). The script is free and available as an appendix.

4.1.1 Data Extraction Results

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology was used for reporting the systematic review result and meta-analyses (Page et al., 2021), as shown in figure 1. In this diagram flow the screening step was done in 5 successive statuses (0 to 4) verifying the relevance of the records to the domain of this study.
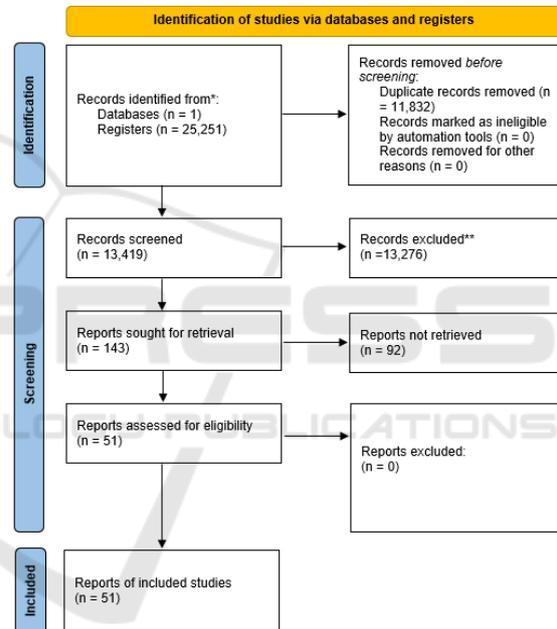

Figure 1: Flow diagram, by PRISMA (Page et al., 2021).

In Status1, 11,832 duplicate records were excluded based on the analysis of the columns "header", "summary" and "date". In Status2, the inclusion (CI) and exclusion (EC) criteria, cited in table 1, were applied, resulting in 143 articles considered valid in this stage. In Status3, the titles, abstracts, and keywords were read to verify if the record in fact met the study domain, resulting in 51 selected articles. Finally, in Status4 these were categorized. Next, we present the results that help to answer RQ1.

4.1.2 Data Synthesis Results

In addition to the variables planned and mentioned in Section 3.5, using data science and natural lan-

guage processing frameworks, it was possible to collect 81 variables in all, the main ones mentioned here: "domain_name", "ipaddress", "latitude", "longitude ", "city", "quarter", "pdf_fullText", "qtd_strings", "topic_dominant", and "sentiment_dominante".

The data synthesis step was carried out based on a short protocol was that summarizes the steps and analysis techniques used in increasing order of complexity. It begins with a temporal visualization by page rank and day of collection and ends with the application of advanced NLP resources, as presented below.

Table 5: Data science, Machine learning and Dataviz Protocol.

	dataviz and machine learning steps
1	Page rank by day of collect data
2	Word cloud
3	Frequency by date
4	Frequency by source
5	Graph analysis of registers
6	Geospatial distribution of the source
7	Sentiment analysis of the total period
8	Sentiment analysis by monthly period
9	Similarity index
10	Q/A with Bert

It is good practice in GL to save eligible records to "*.pdf" (Garousi et al., 2019; Kamei et al., 2021). In addition to allowing records to be preserved, we use python to extract their full text to use as a corpus in the NLP steps of this protocol, for example, to count the occurrence of keywords and to create a Word cloud (Sharp et al., 2017; Russell and Norvig, 2009).

Figure 2: Word cloud - Fulltext of records.

This signal cloud was extracted from the full text of the 51 analyzed records. Next, we present the results of RQ2.

4.2 RQ2: What Are the Cognitive Distances in the Social Representation of the Impacts of Covid-19 in Software Development?

Cognitive distances resulting from different social representations or reported perceptions were identified when analyzing the impact cited in the analyzed text. For that, we use as reference 3 "a priori" classes: People, Projects and Organizations. In summary, the main conclusions about the impacts reported in these classes are:

- 37 registries reported that Covid-19 had a positive impact in SE, 25 reported negative impacts and 21 registries reported both positive and negative impacts.

- Positive impacts on the social representation of the authors of the records benefit people with 25 records. Organizations were cited in 25 registries and projects in 15. Some registries cited impacts in all 3 categories.

- Negative impacts would affect people with 25 records. Organizations with 25 registries and projects in 15.

The topic modeling analysis revealed that the People, Projects and Organizations classes also emerged among the 30 Most Relevant Terms for Topic 1 (40.6% of tokens). This unsupervised classification analysis was generated through Latent Dirichlet Allocation (LDA) and the Sklearn framework (Python) using the full text of the records. The 4 main topic clusters are shown in the following figure.
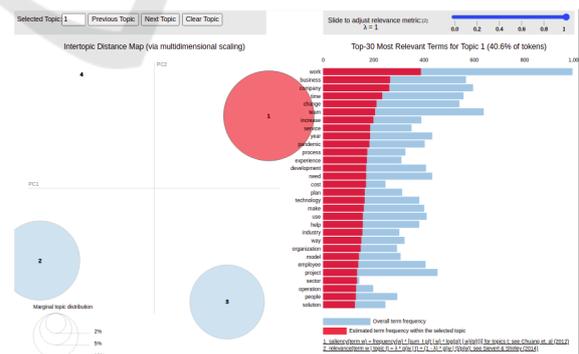

Figure 3: Topic modeling - LDA.

In the GL Frequency by date analysis, it was found that there was a higher concentration of records in the first quarter of 2021 and the second quarter of 2020, respectively.

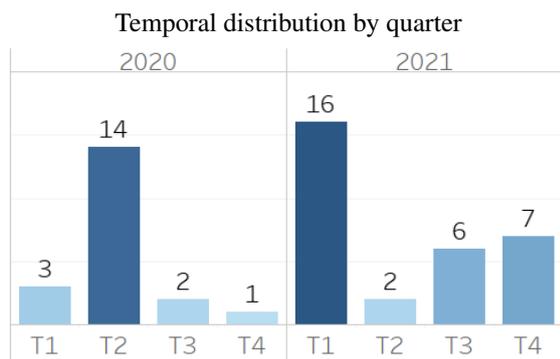It was in the third quarter of 2020 that the first mention of the "work from home" phenomenon was

Temporal distribution by quarter

Figure 4.

related to the hybrid trend, as shown by the following evidence:

- **knowledgehut.com (Knowledgehut, 2022)**, **Evidence:** "Following the pandemic, working from home more frequently (perhaps 2-3 days per week) may become an accepted norm for many companies, as this could realize cost efficiencies and prove that an agile, remote working model is productive." **Date:** 2020-07-24.

This process was intensified in the first quarter of 2021. In addition, other sub-questions helped to answer RQ2, facilitating the analysis of social representations reported through the following previous questions, as shown in Appendix.

The questions about the adopted work model and the ideal work model were classified (Microsoft, 2021b). Figure 5 shows the summary of the results.'
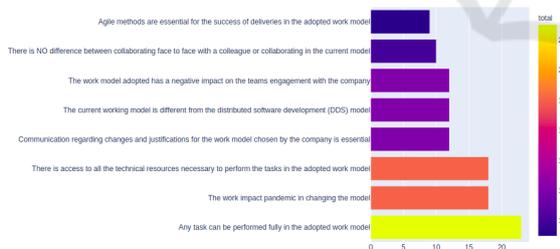

Figure 5: Social representation - RQ2.

The remaining questions were categorized between "Yes" and "No". When a record did not address the question, this record was categorized as NA. The main results are presented below.

4.2.1 Work Model Adopted

Because of the current pandemic situation, the first question, "Check the option that best represents the work model adopted by the company" was categorized in all 51 records as "fully remot". This was the only option identified in the reports during this study.

4.2.2 Work Model Issues

A couple of questions were proposed that could indicate the status of the current and future scenario of Covid-19 impacts on the SE. One of the questions was to see if there are any reports of negative impacts.
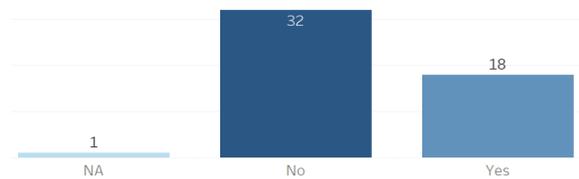

Figure 6: The pandemic had a negative impact on the change in the work model.

The reported social representations indicate that 38 records (or 74.50%) do not consider that Covid-19 has negatively impacted the work model. Followed by 18 records (or 35.29%) who affirm that there is some negative impact. Only 1 record did not report this issue.

When analyzing the impacts of engagement of the teams with the company, according to figure 7, it was found that 12 records (or 23.52%) believe that there are negative impacts of Covid-19. Only 5 records (or 0.98%) affirm that there are no negative impacts, and 34 records did not report this topic.

Figure 7: The work model adopted has a negative impact on the team's engagement with the company.

Another relevant question was to verify if "The current working model is different from the distributed software development (DDS) model", according to 8. In this sense, it was verified that 15 records (or 29.41%) indicate that there are differences between the current remote working model and the model traditionally known as DDS. Followed by 12

Figure 8: The current working model is different from the distributed software development (DDS) model.

records (or 23.52%) do not consider there are differences between the current model and DDS. And 24 records did not mention this topic.

4.2.3 Ideal Work Model

Another aspect worth mentioning is "Check the option that best represents the ideal work model", according to 9. In this sense, we verified that 22 records (or 43.13%) already indicated the hybrid model with flexibility as ideal. Followed by 10 records (or 19.60%) indicating the totally remote model. Only 1 record reported the hybrid without flexibility as ideal and 18 records did not report this topic.
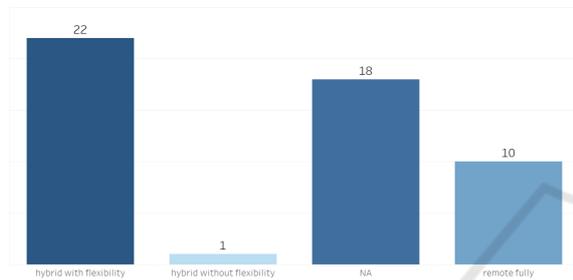

Figure 9: Check the option that best represents the ideal work model.

These were the main results achieved in RQ2. Following are the discussions.

5 DISCUSSION

This research was an important opportunity to transit through interdisciplinarity, necessary and desired in the analysis of any complex problem. Here concepts from Software Engineering, Social Representation, and Sociology were brought together to contextualize the very notion of what "work" is.

The common thread that made it possible to link all these different fields of knowledge was the systematic review of the Grey Literature. The results of this union generated as a benefit a methodological proposal for the automation of the Grey Literature data collection. Moreover, to guide the analytical process, a small protocol was proposed that contains the main steps and techniques often used in text data synthesis, especially when adopting natural language processing (NLP) resources.

The distributions of social representations identified in the observed reports indicate that there is considerable cognitive distance as to the ways in which the Covid-19 pandemic has impacted the SE working model. At some points, there appears to be agreement, but not without distinct points of view.

Still, when analyzing the trend of impact on the work model, one point stood out: the "hybrid model," being reported in 23 records (or 45.09%), considering the possibility of a "hybrid model" of work with or without flexibility.

This finding reinforces what researchers in Sociology such as Domenico de Masi and in Computing such as Silvio Meira have been saying for some time (de Masi, 2021; Meira, 2021). First, more than 40 years ago Domenico de Masi asserted the possibility of remote work. Second, Silvio Meira states that the future is neither totally face-to-face nor totally remote. The author suggests that the future is Phygital, an acronym resulting from 3 dimensions that are the Physical, Digital, and Social dimensions, according to Silvio Meira.

Invariably, whatever the shape of this future of work in software engineering, something new seems to have awakened. This apparent newness is summed up in the desire for flexibility. Everything indicates that it is the notion of this concept and the evolution of this flexibility in the mindset of developers and companies in the software industry that may bring new perspectives and possibilities that will shape the true future of software engineers' work.

6 CONCLUSIONS

The results revealed that at GL there are distant views on the impacts of Covid-19 on software development. The pandemic triggered secondary phenomena that were called, for example, "remote work", "work from home" and flexible work".

These terms are the result of different social representations of the same macro-event, which is the very impact of Covid-19 on the work model. As future work, further research is suggested on the most recent of these secondary phenomena: the "hybrid" model.

Questions such as: What is being a hybrid and what does it imply in the practice of higher education? What would be the guidelines or best practices for a hybrid model to work? These are just a few questions that can help professionals and companies create new disaster risk reduction protocols aimed at building resilience and adaptation in combating the impacts of Covid-19 or future disasters that may impact software development.

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APPENDIX

Here is a link to access the graphs and tables of the data analyzed in this study: https://bit.ly/34k2t3m