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A qualitative study of developers' discussions of their problems and joys during the early COVID-19 months

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Abstract

Many software developers started to work from home on a short notice during the early periods of COVID-19. A number of previous papers have studied the wellbeing and productivity of software developers during COVID-19. The studies mainly use surveys based on predefined questionnaires. In this paper, we investigate the problems and joys that software developers experienced during the early months of COVID-19 by analyzing their discussions in online forum devRant, where discussions can be open and not bound by predefined survey questionnaires. The devRant platform is designed for developers to share their joys and frustrations of life. We manually analyze 825 devRant posts between January and April 12, 2020 that developers created to discuss their situation during COVID-19. WHO declared COVID-19 as pandemic on March 11, 2020. As such, our data offers us insights in the early months of COVID-19. We manually label each post along two dimensions: the topics of the discussion and the expressed sentiment polarity (positive, negative, neutral). We observed 19 topics that we group into six categories: Workplace & Professional aspects, Personal & Family well-being, Technical Aspects, Lockdown preparedness, Financial concerns, and Societal and Educational concerns. Around 49% of the discussions are negative and 26% are positive. We find evidence of developers' struggles with lack of documentation to work remotely and with their loneliness while working from home. We find stories of their job loss with little or no savings to fallback to. The analysis of developer discussions in the early months of a pandemic will help various stakeholders (e.g., software companies) make important decision early to alleviate developer problems if such a pandemic or similar emergency situation occurs in near future. Software engineering research can make further efforts to develop automated tools for remote work (e.g., automated documentation).

Keywords Developers' discussions · devRant · COVID-19 · Sentiments

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1 Introduction

COVID-19 has changed how we work and balance our life (Sadeghloo and Mikhak 2022; Dubey et al. 2020). While governments across the world took aggressive economic measures to support the failing economic conditions (G of Canada 2020; Rosen and Ramer 2020), many have lost their jobs (Coronavirus Unemployment 2020; Coronavirus Layoffs Remake Silicon Valley Job Market 2020; Coronavirus Impact 2020). The economic stress coupled with the lockdown have dramatic impacts like mental illness (Harper et al. 2020; Bracha and Burkle 2006; Kim et al. 2015; Roberto et al. 2010). Several studies analyzed the wellbeing and productivity of workers during the pandemic by drawing on parallels (e.g., natural disaster, by taking examples from influenza of the last decade) (Dall'Ora et al. 2016; Donnelly and Proctor-Thomson 2015; DiGiovanni et al. 2005; Evers et al. 2014; Blake et al. 2010). Yet, the sudden but global and prolonged periods of COVID-19 have made this pandemic unique and thus challenging. It is well-understood by now that economic, social, and mental impacts of the pandemic can be quite extensive and prolonged (Meltzer et al. 1999; Prati et al. 2011; Teasdale et al. 2011; Thommes et al. 2016).

COVID-19 has affected almost every profession and every aspect of lives (Meltzer et al. 1999; Prati et al. 2011; Teasdale et al. 2011; Thommes et al. 2016). Software developers are no exceptions (Coronavirus Unemployment 2020). As in April 2020 we started to observe lockdown across the world, we decided to study what aspects of software developers' lives are affected due to the pandemic and how they reacted to the challenges of the pandemic. Our aim was to understand the aspects and the reactions of software developers as broadly as possible (i.e., both technical or non-technical aspects). We seek insights that we can gain based on unfiltered/open discussions of the developers. An in-depth understanding of such aspects during the early phases of the pandemic can help us better prepare for a future pandemic.

As the pandemic moved beyond 2020, several papers in Software Engineering (SE) research were published that analyzed how software developers were impacted during the pandemic. A large body of these studies used surveys of software developers to understand issues like the impact of work from home, work-life balance for developers with families, and relationships with managers (Ralph et al. 2020; Russo et al. 2021a; Oliveira et al. 2020; Bezerra et al. 2020; de Mendonca et al. 2020; Machado et al. 2021; Butler et al. 2021; Rodeghero et al. 2021; Miller et al. 2021; Russo et al. 2021b; Wang et al. 2021b; NicCanna et al. 2021). However, a survey can only ask predefined questions. This approach can be counter-intuitive for a "black swan" event like COVID-19. Therefore, with a predefined set of questionnaires, we might miss insights in the current studies due to the closed nature of surveys. Another group of empirical studies analyzes code repositories to assess the change in productivity in developers in terms of code metrics (Bao et al. 2020; Rahman and Farhana 2020; Wang et al. 2021a). However, focus on code can lead to the non-technical aspects being missed. Finally, Silveira et al. combine findings from the temporal analysis of code repositories and a survey of software developers (Silveira et al. 2021).

Intuitively, a comprehensive catalog of technical and non-technical aspects can be obtained by observing "water cooler conversations" between the developers. Given the work-from-home regulations imposed as part of the pandemic control measures, online forums might act as a "virtual water cooler". We are, however, not aware of previous research of the COVID-19 impact on software developers that analyzed such discussions of developers in online forums.

Not all online developer forums support both technical and non-technical discussions. On the one hand, many platforms targeting developers focus on the technical aspects of software development. For example, Stack Overflow explicitly restricts discussions to "a specific programming problem, or a software algorithm, or software tools commonly used by programmers",[1] while opinions expressed in issues in GitHub projects can be expected to be focused on the project-specific concerns. Other developer forums like DEV.io also put more emphasis on technical Q&A. On the other hand, generic online platforms like Twitter/Reddit/Quora are open to every registered user and as such, the discussions on those platforms can be too noisy to get insights related to software development. To that end, we found devRant (Fox and Rogus 2014), an online developer forum that encourages software developers to share their frustrations and joys of everything related to their life. The devRant platform was introduced on May 14, 2016. As of August 13, 2020, the site has over 200K posts, called 'rants'. The posts were voted around 6.8M times by more than 50K developers from all around the world. Unlike technical developer forums like Stack Overflow, devRant allows developers to discuss and share both technical and non-technical aspects of their life. When COVID-19 was declared a pandemic in March 2020, we observed a growing number of discussions from developers about COVID-19 in devRant. The posts contained discussions of technical and non-technical aspects of developers' lives attributed to COVID-19.

In this paper, we collected 825 posts from devRant between January and April 12, 2020. Each post contained one or more COVID-19 related tags/search terms (e.g., corona, covid). WHO declared COVID-19 as pandemic on March 11, 2020. As such, our data offers us insights about the early months of COVID-19. We manually analyze each post to determine the type of topics discussed in the post. We also manually label each post a sentiment polarity. A sentiment polarity can be positive, negative, or neutral. We find in total 19 topics related to socio-technical aspects of life that developers attributed to the COVID-19 crisis. The 19 topics can be grouped under six categories: workplace & professional aspects, personal & family well-being, technical aspects, lockdown preparedness, financial concerns, and education & Societal concerns. The topics around the two categories, workplace & professional aspects and personal & family well-being are discussed the most. We also find the developers are worried about the impact of a sudden shift towards teleworking on their professional, personal, and family life. For each topic, we find both positive and negative discussions from developers. Around 49% of the discussions are negative, while around 26% are positive. The discussions around financial concerns and lockdown preparedness are the most negative. We find evidence of developers' stress to cope with this unique situation and stories of their job loss. We also find positivity in the developers to support each other and the COVID-19 awareness by leveraging their skills.

In Table 1, we summarize the research contributions and advancements made by our study. We observed similarities with and differences from current research on COVID-19 for SE. Our observation of a decline in productivity and wellbeing is consistent with current survey-based study findings (Ralph et al. 2020; Russo et al. 2021a). In addition, we find new evidence like lack of motivation due to social isolation, loss of productivity due to the absence of experts/documentation, etc. We find that developers are not happy with micromanagement and increased monitoring. To the best of our knowledge, our research is the first to offer direct evidence from developers on their struggles due to loss of job/income during the pandemic.

[1] https://stackoverflow.com/help/on-topic Consulted on Jan 3, 2022.

Table 1 Summary of research contributions and advancements made by our study

Type	Research contribution	Research advancement
Aspects of software developers' life impacted by COVID-19	We observed 19 aspects of developers' life that are affected during the early periods of COVID-19. The 19 topics are grouped into six categories: Workplace and Professional, Personal and Family Wellbeing, Technical, Lockdown Preparedness, Financial Concerns, and Education and Societal Concerns.	Our research results are similar to previous study findings on workplace/ professional and wellbeing aspects. We find new evidence on four other categories, i.e., technical, lockdown preparedness, financial concerns, education and societal concerns. We are aware of no previous research that showed evidence of developers' worries about job loss, or offered direct evidence from developers on their thoughts of personal development.
Reactions of the developers towards the aspects	We analyzed the sentiment expressed by developers in each of the 825 posts that we analyzed. Around 49% of the posts have negative sentiment polarity, while 26% are positive and the rest are neutral. We report the sentiments expressed per the 19 aspects and across the six aspect categories. The discussions around financial concerns and lockdown preparedness are the most negative, while technical aspects have the highest number of posts with positive polarity among the six aspect categories.	We are aware of no previous research that analyzed the sentiment of developers towards the different aspects of their lives that are affected by COVID-19. While the studies generally perceive that developers are negatively affected, our study shows that the negativity is not evenly spread across all the six aspect groups. Such findings can help prioritize policies and rules to address the problems. The findings can also motivate the design of more focused surveys and empirical studies (e.g., around an aspect category).

Our study findings offer implications to various stakeholders in SE. Software organizations could find a better way to communicate and to engage with their employees during a pandemic like COVID-19 to improve their well-being and productivity. Software practitioners can devote more time to write and improve documentation of the software products that they develop, so that other team members can continue the development during a pandemic without much guidance. Software engineering researchers can devote more time to develop techniques to make it easy to design and implement scalable software products.

Replication Package contains the entire dataset with labels of all topics and sentiment polarities in https://github.com/giasuddin/Covid-devRant-Appendix.

2 Study Setup

Our goal is to understand what aspects of software developers' lives are affected due to the pandemic and how developers reacted towards those affected aspects. We focus on the early periods of the pandemic. We answer two research questions:

RQ1. What aspects of software developers' lives and professional activities are attributed to COVID-19 during the early periods of the pandemic?
RQ2. What sentiments do the developers express towards those aspects?

We use developer discussions in an online social forum, devRant to answer to our two RQs. Our data collection and analysis process involved four major steps (see Fig. 1). First, we collect devRant posts that contained technical and non-technical discussions of developers that they attributed to COVID-19 (in Steps 1 - 3). Second, we manually label each relevant post to determine the type of aspects discussed (RQ1) and the sentiment polarity expressed (RQ2) (in Step 4).

1. **Identify Covid-19 Related Tags** (Section 2.1). We identify 30 tags in devRant related to COVID-19 discussions between January 2020 to April 12, 2020.
2. **Download Posts** (Section 2.2). The 30 tags together were used to label total 919 posts in devRant. We download the posts on April 13, 2020.
3. **Filter Posts** (Section 2.3). We manually check each downloaded post to determine its relevance to COVID-19. We found total 825 relevant posts.
4. **Data Analysis** (Section 2.4). We manually assign each of the 825 posts two types of labels: topic (RQ1) and sentiment (RQ2). Topic denotes the type of discussions in a post that is attributed to COVID-19. Sentiment denotes the overall sentiment polarity expressed in the post.

April 12, 2020 marks exactly one month since the COVID-19 was declared a pandemic by WHO in April 11, 2020. As such, our data covers developers' COVID-19 related discussions during the early COVID-19 periods, when the spread of COVID-19 influenced the rapid transition of developers to work from home.

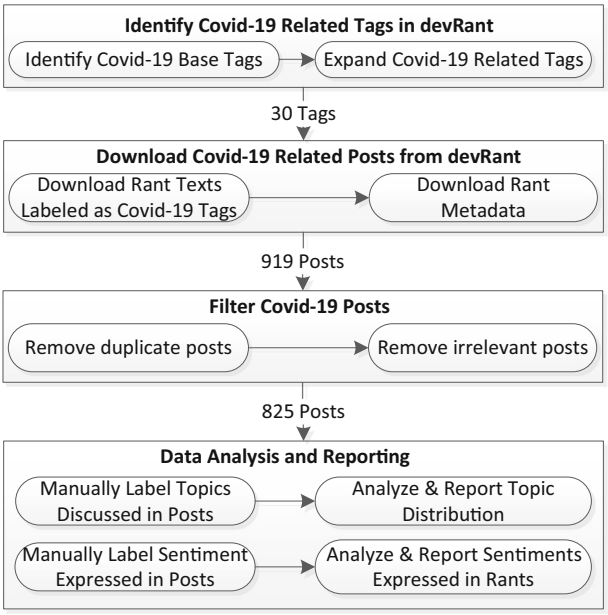

Fig. 1 The major steps we followed in the study

2.1 Identify Covid-19 Related Tags

We analyzed all three types of posts from the devRant platform.

- **Rant.** Describing an issue/event related to a developer's life.
- **Story.** Describing a development/life incident.
- **Collab**. Asking for support to build a project or to solve a technical issue.

A post is associated with a list of tags given by the author. Developers can respond to a post by providing 'comments'. Users can upvote and downvote the rants.

We collect total 30 tags from devRant that contained posts with discussions about COVID-19. Using pydevrant API (Rosa 2020) we first identify 11 base tags in devRant that can be used to intuitively describe the pandemic and that developers in devRant used to tag a post when they discussed COVID-19 in the posts (e.g., coronavirus). Next we add 19 more tags by analyzing the co-occurrence of the tags with the 11 base tags. We discuss the two steps below.

Identify Base Tags. On April 13, 2020 we searched for the devRant site for 11 tags related to COVID-19 using the pydevrant API (Rosa 2020). The tags are: (1) covid, (2) covid-19, (3) covid19, (4) corona, (5) coronavirus, (6) corona+virus, where we use a '+' sign to denote a space in the search API, (7) pandemic, (8) quarantine, (9) lockdown, (10) 2019-ncov, and (11) pig+flu

The first two authors picked the 11 base tags after consulting each other, the literature (e.g., Ralph et al. 2020), and by analyzing random devRant posts. For example, several tags are intuitive to determine given the tags denote the pandemic with similar six keywords: 'covid', 'covid-19', 'covid19', 'coronoa', 'coronavirus', and 'corona virus'. As we can see, each of these keywords simply refer to the COVID-19 using various combination of 'covid'/'corona'/'virus' keywords. Therefore, the two authors started to search devRant using the above keywords. The purpose was to see whether each keyword is also found as a tag in the devRant post. On April 13, 2020 we found at least one tag denoting the above six keywords. We thus kept each as a base tag. We then randomly analyzed several devRant posts labeled by the six tags. The purpose was to see if those posts have other tags that could denote the pandemic. We found that developers in devRant also used the following five tags in the posts we checked: pandemic, quarantine, lockadown, 2019-ncov, and pig flu. The tags (pandemic, quarantine, and lockdown) are also used to refer to discussions like the impact of lockdown or quarantine and the preparation to survive during the pandemic, etc. The tag '2019-ncov' refers to the earlier code name of COVID-19. The tag 'pig flu' was used by some developers to discuss the origin or spread of the virus, which during the early phase of the pandemic was perceived as a virus transmitted from pigs to humans.

As discussions around COVID-19 evolved in devRant during the early months of 2020, we noticed some other tags are also used for posts containing COVID-19 discussions. We thus expand our list of base tags as follows.

Expand Base Tags. We add 19 more tags into our list of COVID-19 related tags as shown in Fig. 2. First, we crawled the entire devRant site to collect all the posts that we can find by using the 11 base tags. We used the pydevrant API (Rosa 2020) to search for posts labeled with the tags. Second, we collect the list of all tags that were co-mentioned in the posts that are labeled with the 11 base tags. We found total 266 co-mentioned tags. Third, we manually analyze the 266 co-occurred tags and pick 19 more

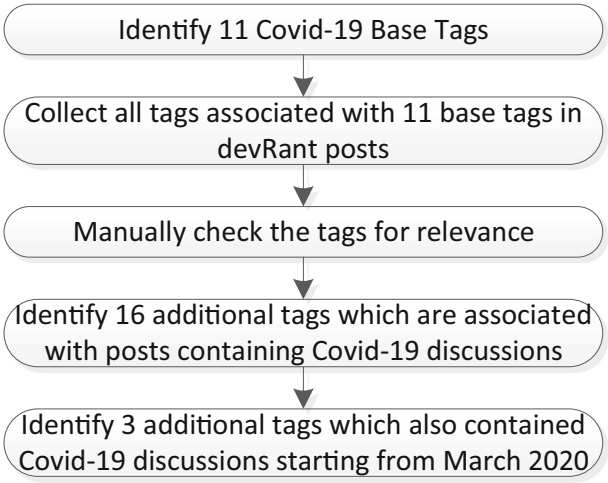

Fig. 2 Steps followed to expand the list of base tags

tags, where each of those tags was used to label one or more posts that contained COVID-19 related discussions. The 19 tags are: (1) wk199, (2) wk200, (3) wk201, (4) wk203, (5) working+from+home, (6) wfh, (7) isolation, (8) telework, (9) video+conferencing, (10) apocalypse, (11) bat+attack, (12) virus, (13) COVID-19+global+hackathon, (14) jaicorona, (15) random, (16) question, (17) devrant. (18) joke/meme, and (19) rant.

The first four tags (wk199–wk203) denote week numbers in devRant. In devRant wk1 denotes the week devRant was created. The four weeks are the four weeks preceding April 13, 2020. WHO declared COVID-19 a pandemic in the second week of March 2020. We found that developers in devRant started discussing COVID-19 related issues in the posts labeled with simply the weekly tags. We did not find any tag for wk202 in devRant (for the week of March 30, 2020), but the tag 'rant' contained discussions for that week.

Starting from January 29, 2020, we found that developers started discussing about COVID-19 in posts tagged as the last 15 tags among the 19 tags. For example, the following post is tagged as 'wfh' (work from home): "*I've been working exclusively from home for over 2 years now. I've been seeing several posts from people talking about adjusting to working from home, so I figured I would compile a list of tips I've learned over the years to help make the adjustment easier for some people. ...*" ($R_{2453544}$, where the subscript refers to the ID of the devRant post). The developer posted this in March 2020 by offering some suggestions to work from home effectively. The post does not refer to COVID-19, but given the time and context of the post, it is considered as relevant. While some of the tags (e.g., working from home) are more specific to the COVID-19 situation, others are generic like random, question, devrant, joke/meme and rant. As we show in Fig. 3, the first COVID-19 related post was created on January 29, 2020 (the week when WHO, for the first time, officially reported the number of deaths due to COVID-19).

2.2 Download Posts

For the 11 base tags, we collected all the posts from devRant labeled with the tags. For the 19 expanded tags, we first downloaded all the posts starting from January 20, 2020.

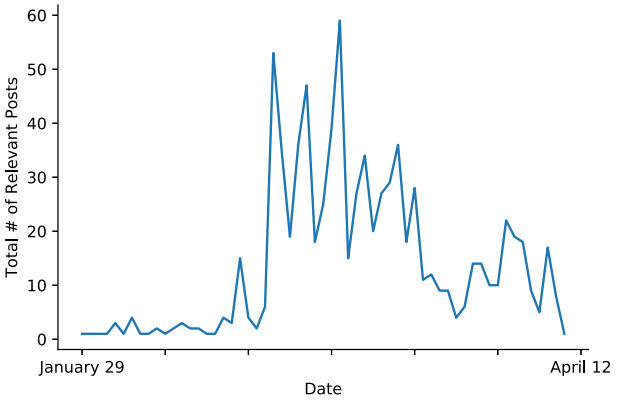

Fig. 3 The distribution of new distinct relevant devRant posts containing COVID-19 related keywords for each date between January and April 12, 2020

However, after some manual check, we found the earliest date with COVID-19 discussion remained the same across all the posts labeled by the 30 tags, i.e., January 29, 2020. For the 19 expanded tags, we thus downloaded posts that are created on or after January 29, 2020. We downloaded the following meta information per post using the pydevrant API: 1. Textual content. 2. Score. The score of a post is computed as (#upvote - #downvote). Upvotes and downvotes to a post are given by devRant users. An upvote is denoted with a '+' sign and a downvote is denoted with a '−' sign. 3. Creation time. 4. Tags. Overall, we downloaded 1100 posts. After removing the duplicates, we had 919 posts.

2.3 Filter Posts

Not all 919 posts that we downloaded could be related to COVID-19. This could happen when a post is labeled with one of the 30 tags, but our manual observation of the post content failed to understand the connection between COVID-19 and the post content. We, therefore, formally define the following inclusion and exclusion criteria to include/discard a post.

- "Relevant". If the post explicitly or implicitly refers to a certain aspect of life that is impacted by the pandemic.
- "Irrelevant". Otherwise, i.e., we were unable to determine any specific aspect from the discussion that could be attributed to the pandemic.

To determine the relevance, the authors relied on the following information: (1) Post content (text and images), (2) Comments as replies to a post, (3) any image/link provided to the post, and (4) Date and time of the posts. This is to ensure that we have better understanding of the underlying context.

We apply the above criteria on each of our 919 posts. The first two authors jointly inspected each post. We provide an example below to illustrate our decision making process. The following post was created on March 30 but we did not consider it as relevant due to no plausible connection with COVID-19, "*The chocolate ration has gone up.. It's 1984 all over again I notice: ... You try and help by asking questions, or suggesting solutions, and your posts get removed on the grounds of fake news!...*" ($R_{2445775}$) This post had a url which was removed by the user/devrant. The post referred to the a Guardian anti-fake news

unit dealing with 10 false coronavirus articles. We decided to consider the post as irrelevant, because we failed to establish the connection between the post content and the life of a software developer. In total, we filtered out 93 posts as irrelevant.

In Fig. 3, we show the distribution of the 825 relevant posts by their creation dates. The first post with explicit mention of COVID-19 in devRant was created on January 29, 2020. This is intuitive, given WHO first officially confirmed 8K COVID-19 cases worldwide on January 30, 2020. There is a notable spike of COVID-19 discussions in devRant starting from the mid of first of week March. WHO declared the COVID-19 as a pandemic on March 11, 2020 (WHO 2020). While substantial discussions of developers with COVID-19 mentions occurred throughout the month of March 2020, there is a notable drop of the COVID-19 mentions in posts created in April. Indeed, we do not observe much discussion with explicit mentions of COVID-19 in the posts created after April 12, 2020. This finding denotes that developers in devRant started to be accustomed to their new life during pandemic or to become busy with the new setup of their life. Therefore, their expression of any COVID-19 related concerns in devRant might have become more implicit/subtle after April 12, 2020. We, therefore, might need more than tags to find such concerns in those posts (i.e., posts created after April 12, 2020). We leave an analysis of such COVID-19 discussions as our future work.

In Table 2, we show statistics of relevant posts per tag in our dataset. We sort the tags based on the total number of posts we downloaded per tag in 2020. The highest number of posts was found under tag 'rant', which is the most popular tag in devRant (and a default unless a user explicitly assigns another tag). A post can have more than one tag in our dataset. The earliest relevant post appeared on January 29, 2020 at 1:14:42 UTC. The post was a rant "*Y Gets severe vertigo when laying down starting yesterday. Most likely because I worked 110 hours last week. Brain: "coronavirus, panic" Not even a hypochondriac but even I'm a little on edge because of the plague.*" The post was labeled with the 'rant' tag. The third column shows the relevancy ratio of posts per tag. For some posts, the ratio is below 90%. This is mainly because several posts under those tags were posted more than once in devRant, which we filtered out as 'irrelevant' (i.e., kept only one out of all the duplicates). A post can also have multiple tags from our list of 30 tags. At the end, we have 825 distinct relevant posts from devRant that we use for our data analysis and reporting. Despite our extensive efforts to collect and filter all COVID-19 discussions as of the time of analysis, we may still miss some relevant discussions. We discuss this threat to our data collection in Section 5.

The 825 relevant posts have an average score of 13.2 (min = 0, max = 203, standard deviation = 17.4). The votes are provided by users in devRant. The posts were created by a total of 407 distinct users.

2.4 Data Analysis

We manually analyze each of the 825 posts along two dimensions:

- Topic Discussed (RQ1). We identify the topics discussed in a post that are attributed to COVID-19. A topic can denote a technical or non-technical aspect of a developer life that is attributed to COVID-19.
- Sentiment Expressed (RQ2). We assign each post a sentiment polarity label based on the overall sentiments expressed in the post. A sentiment polarity can be positive, negative, or neutral.

Table 2 Statistics of the posts per the 30 tags (#All = all posts, #Rel = relevant)

Tag	#All	#Rel	#Rel/#All	First date relevant
rant	590	544	92%	1/29/2020 1:14
wk199	170	162	95%	3/9/2020 0:41
covid-19	162	142	88%	3/5/2020 7:31
coronavirus	145	119	82%	3/8/2020 1:08
joke/meme	135	116	86%	2/1/2020 14:10
random	127	107	84%	1/30/2020 23:17
corona	72	57	79%	2/1/2020 14:10
wfh	58	56	97%	3/10/2020 10:32
question	54	47	87%	2/13/2020 13:31
quarantine	52	49	94%	3/15/2020 14:52
coronoa+virus	48	36	75%	2/8/2020 22:36
covid19	43	36	84%	3/9/2020 2:13
lockdown	34	30	88%	3/14/2020 21:07
wk200	31	30	97%	3/16/2020 7:24
covid	30	26	87%	3/13/2020 10:06
devrant	27	24	89%	3/13/2020 10:43
wk203	21	21	100%	4/6/2020 1:15
wk201	13	13	100%	3/23/2020 1:05
working+from+home	11	10	91%	3/17/2020 6:18
pandemic	11	11	100%	3/19/2020 18:25
virus	9	7	78%	1/31/2020 0:08
apocalypse	9	6	67%	3/13/2020 12:51
bat+attack	5	3	60%	3/17/2020 16:44
isolation	5	5	100%	3/29/2020 12:42
pig+flu	4	3	75%	3/12/2020 17:52
covid-19+global+hackathon	4	3	75%	4/11/2020 5:48
2019-ncov	4	4	100%	2/8/2020 22:36
jaicorona	4	4	100%	3/17/2020 1:38
telework	3	3	100%	3/31/2020 20:18
video+conferencing	3	2	67%	3/14/2020 12:28

For manual analysis of each post to label the topic, we used an open coding approach (Miles and Huberman 1994). Open coding includes labeling of topics/categories in textual and graphical contents (e.g., in the images in a post) based on the properties (e.g., technical/non-technical aspects) and dimensions (e.g., a COVID-19 related situation) about which the contents are provided. In our open coding, we followed the principles of card sorting approach (Hudson 2013). In card sorting, the contents are divided into cards, where each card denotes a conceptually coherent topic. In our case, each post's content is considered a card. Given the entire data analysis happened virtually during COVID-19, we conducted the approach as follows. We created a spreadsheet in Google Drive, where each row contained information about a post (e.g., post text, devRant url of the post, post ID, post tag, etc.). Then the first two authors met over Skype on multiple sessions to determine whether a post is relevant and if so which topic(s) it discusses. For a given post, one of the authors put

his labels. Then the two authors met over Skype to discuss the labels together. To mitigate bias, the first two authors discussed together the topic(s) discussed in each post. A post can have one or more topic, each denoting a technical or non-technical aspect of developer life that is attributed to or impacted by COVID-19. The two authors jointly labeled the posts on multiple iterations. Due to the COVID-19 restrictions, the two authors conducted the entire analysis virtually. When in doubt to understand the post contents, the authors also checked the comments to a post. For example, consider the following post "*Working from home is nice. Mastering to separate work from home is nicer.*" $R_{2089958}$ There are five comments in response to the post like the following "*Getting out from bed when you work from home is first step.*" The second comment is "*second step is attending Skype meeting wearing more than underwear*". Such comments offer validation that the post is about teleworking.

The two authors also consulted together to assign an overall sentiment polarity to a post. This means that we do a document-level sentiment polarity assignment, where we assign a polarity label to the post based on the overall sentiment expressed in the post. For sentiment polarity assessment, we followed the emotion taxonomy of Shaver et al. (1987). The taxonomy is defined as a hierarchical tree of emotions that organizes emotion levels into clusters. Within a cluster, each level is refined to offer increased granularity. This allows, at the top level, the classification of six types of emotions: love, joy, anger, sadness, fear, and surprise. The same taxonomy was previously used by Calefato et al. (2018) during their development of an SE benchmark for the sentiment polarity. Similar to Calefato et al. (2018), we identify emotions in the text and map the emotions into positive (e.g., love, joy), negative (e.g., anger, fear, sadness), and neutral polarity (i.e., no positive or negative emotions were found). Consider the following post: "*Remote work for everybody! It's actually great: get to cook my own lunch, saves an hour in commuting. I just need to move forward my plans for a beefier personal workstation and generally more functional work-at-home environment.*" $R_{2427726}$. The first sentence talks about work from home; hence, it was labeled with the *Telework* topic. The second sentence discusses home workstation setup; hence, it was labeled with the *Ergonomics* topic. The sentiment expressed here was positive.

Once we finish the assignment of topics to all the 825 posts, the first two authors then discuss together again to group the topics into higher categories. We analyze each topic individually as well as within the context of other topics to determine how the theme found in the topics may be similar to or different from each other. This exercise helped us cluster similar topics into several higher-level categories. For example, we group both the 'Telework' and 'Ergonomics' topics above under one category 'Workplace and Professional Aspects'.

3 Study Results

We found a total of 19 different topics that developers in devRant attributed to the COVID-19 crisis between January 29–April 12, 2020. In Table 3, we present the 19 topics and group those by six categories. The categories with higher frequency (i.e., occurrences) are placed at the top. The 'Count' column shows the total number of occurrences of a topic. The last column 'Polarity Distribution' shows the percentage polarity distribution of each topic. The six categories are as follows.

1. **Workplace and Professional Aspects** category contains topics related to remote work and productivity while managing coworker relationships.
2. **Personal and Family Wellbeing** category contains topics related to the maintenance of work life balance during the COVID-19 crisis.

Table 3 The topics discussed with polarity distribution in % of sentiment polarity classes, black (Negative N), dark-gray (Neutral O), light-gray (Positive P)

Category	Topic	#	Polarity distribution (in %)		
			N	O	P
Workplace & Professional Aspects (580)	Telework	347	52.1	22.5	25.4
	Relationship	117	71.8	8.5	19.7
	Productivity	51	47.1	11.8	41.2
	Ergonomics	32	46.9	9.4	43.8
	Travel Issues	33	45.5	18.2	36.4
Personal & Family Wellbeing (362)	Entertainment	147	26.5	54.4	19.0
	Health & Safety	106	58.5	28.3	13.2
	Family & Friends	58	56.9	17.2	25.9
	Work Life Balance	51	45.1	15.7	39.2
Lockdown Prepare (305)	Coping	234	53.0	23.5	23.5
	Awareness	71	52.1	22.5	25.4
Technical Aspects (282)	Development	168	35.7	33.9	30.4
	Technology	92	52.2	25.0	22.8
	Security	22	50.0	27.3	22.7
Financial Concerns (123)	Jobs & Finance	101	65.3	15.8	18.8
	Business	22	59.1	22.7	18.2
Education & Societal Concerns (115)	Education	53	45.3	26.4	28.3
	Law & Politics	52	69.2	15.4	15.4
	Environment	10	10.0	0.0	90.0

3. **Lockdown Preparedness** category contains topics related to the awareness and coping with pandemic.
4. **Technical Aspects** category contains topics related to the technical challenges developers face while working remotely.
5. **Financial Concerns** category contains topics related to the monetary and job uncertainty developers face during the pandemic.
6. **Societal Concerns** category contains topics with regards to developers' concerns about the society in general, such as law and order.

The topics related to 'Workplace and Professional Aspects' were discussed the most (580 times), followed by the categories 'Personal and Family Wellbeing (362 times)', and 'Lockdown Preparedness (305 times)'.

Overall, almost half of the posts (49.2%) contain negative sentiment polarity (see Fig. 4). The posts with positive sentiment account for 25.7% of all posts. Out of the six categories,

Fig. 4 Percentage distribution of sentiment polarity across all the relevant posts

the negative polarity accounted for more than 50% of the discussions for four categories: Workplace & Professional Aspects (53.6%), Lockdown Preparedness (52.2%), Financial Concerns (65.8%), and Education and societal concerns (53.1%). As we discuss later with evidence from developers, the higher prevalence of the negative polarity across the topic categories is due to problems developers faced during the COVID-19 crisis. Among the other two categories 'Personal & Family Wellbeing' has 43.9% of the posts are negative and 20.9% are positive. For the category 'Technical Aspects', around 41.4% of the posts are negative and 26% are positive. We find discussions from developers in this category, who were working remotely even before the pandemic. As such, they had necessary technical setup already in place prior to the pandemic. As such developers were less negative about technical aspects category than the other categories.

In the following subsections, we answer our two research questions together, by following our six topic categories along with the sentiments expressed.

3.1 Workplace & Professional Aspects

53.6%Negative
30.1%Neutral
16.2%Positive

Five out of the 19 topics in our dataset are related to developers' workplace and professional aspects. Around 75% of the posts in our dataset contain discussion at least one of the six topics. The topics are (in order by frequency): remote working (i.e., telework), coworker/manager relationship, productivity, ergonomics, place of stay and travel issues during quarantine. Overall, around 55% of the discussions related to the six topics are of negative polarity and 32% are of positive polarity. The negative polarity expressions are due to the uncertainty and challenges developers faced during the pandemic with their jobs, coworkers, home office setup, and productivity. The positive expressions are mainly due to the fact that many of the developers actually enjoyed working remotely and the pandemic gave them an opportunity to do it all the time. We discuss the six topics with examples below. For each topic, the bar shows the overall sentiment polarity distribution from Table 3, i.e., black (negative), dark-gray (neutral), and light-gray (positive).

3.1.1 Sudden Shift Towards Telework

52.1%Negative
22.5%Neutral
25.4%Positive

In our dataset, we find that the pandemic has caused concerns among developers about coping with the 'new normal' work environment and the overall company policy to monitor employees while working from home. The developers in in our dataset expressed concerns about different aspects related to telework. The developers were concerned about how their companies were handling the shift from office to work from home transition. They also reported to have experienced refusals from companies to allow them to work from home.

✗ $R_{2435953}$ ***Refusal to do Remote Work.*** "*My [expletive] employer won't allow work from home saying unless government enforces it, he can't allow it and reason he is giving is that wE wOn't be AbLE tO communicAtE via SkyPE?*"
✗ $R_{2430220}$ ***Refusal for Consultants on Teleworking.*** "*The place I work at doesn't allow homeworking for consultants.*"

The remote work environment has also created challenges for managers and employees to properly communicate during meetings.

✗$R_{2436391}$ ***Difficulty to Engage Coworkers in Remote Meetings.*** "*I finally realize why the managers at my work are so against remote work. We've gone remote now and had a meeting yesterday that somewhat demanded people to be engaged. I have never seen such grown up and otherwise professional people act so irresponsible. Managers had to raise their voice towards 30+ year olds in order to get their attention.*"

Compared to non-tech employees in a company, developers are most likely used to working from home even before the pandemic. Developers cited that they now see new appreciation from their non-tech colleagues towards telework. Overall, around 32% of developers discussions around teleworking were positive.

✓$R_{2430983}$ ***Non-Tech vs Tech Workers.*** "*Non tech coworkers before COVID-19: you don't need home office, it's only a way to avoid job responsibilities. Non tech coworkers today: yeah home office is a great idea, why we didn't think about it before*"

Developers from different countries shared their concerns in devRant. We find that a developer from Australia worries that the pandemic has made Australia an isolated island, while a developer from the Netherlands seem to have mixed feeling about working from home.

✗$R_{2438831}$ ***Australia.*** "*Well that's it folks, Australia has started to shutdown and become the isolated island it once was again.*"

✓$R_{2439915}$ ***Netherlands.*** "*So who hates working from home? Here in the Netherlands quarantine was postponed till June 1st, so 2 more months WFH for us. Yeahhh...*"

3.1.2 Coworker Relationships

71.8%Negative
8.5%Neutral
19.7%Positive

Developers expressed their concerns about the management of coworker relationships remotely during the pandemic. The concerns stem from getting increased workload from managers and troubles in communicating with co-workers to complete daily development tasks. More than 72% of such discussions are negative, i.e., co-worker relationship management during pandemic and over online is a significant challenge for developers. Developers find that they are subject to elevated level of monitoring and communications with their managers during pandemic, and they are mostly unhappy with it.

✗$R_{2439836}$ ***Increased communication with boss.*** "*Boss: ***Calls for the 15th time in a day...*** Me: (With Bleeding Ears) Yes sir, am here...! (Having to pick up every single time as he knows you've got nowhere to go 'coz the whole city is in LockDown) Boss Talks for another 1 hour with screen share. My Boss is a bigger threat to my health than Corona now!!! #GoCoronaGo*"

✗$R_{2434425}$ ***Elevated monitoring.*** "*Senior: "we can go remote now, but you have to report what you did at the end of the day. Ex: 7am clock in work on bla bla to 10am. 10am–12nn still working on bla bla. Til end of day." What a crap. Now I don't want to work remote with this bunch of reports at the end the day. Some [expletive] in here.*"

Some developers asked suggestions from others on how to deal with their managers who were micro-managing during the lockdown.

✗$R_{2441282}$ ***Coping with micro-manager.*** "*How do I tackle a team lead who is micro-managing us like hell during this quarantine?*"

The developer who shared the above post, offers more details of the level of micro-management in the comment to the above post. He notes the employees in his work were required to let their manager know of their availability every hour: "*... we're even supposed to log our whole day in advanced, hour by hour, letting him know what we are working on at a particular hour, or when we are taking a break larger than 20 mins*". Other developers offered their support to him by providing suggestions as follows: "*Make it clear and simple that you don't want to be micromanaged as it reduces your productivity and comfort You could have two checkpoints. One at the Beginning and the other near the end of the day. That's actually enough*"

Software development is a social activity, given that developers need to work in teams to develop solutions. Personal bonding that developers grow via in-person communication is crucial and a sudden shift towards remote working made it impossible for developers to develop such rich social bonding with their fellow co-workers. For many developers, the friends at work account for the bulk of their social life. For many other developers, the office environment offers more flexibility to work productively and to communicate with their co-workers. As such, these developers were not happy with their remote working from home during the pandemic.

✗$R_{2431063}$ ***Missing team social life.*** "*i hate working from home.. my team Is all the social life i have. Already miss them after 1 day.*"

✗$R_{2427751}$ ***Flexibility of office environment communication with colleague.*** "*I'm more comfortable working in the office, as the environment is set up better, and I can chat with colleagues more easily when needed.*"

3.1.3 Up and Down Productivity

47.1%Negative
11.8%Neutral
41.2%Positive

We observed insightful discussions about productivity of developers during pandemic. In general, developers expressed lack of motivation to work on projects, while they are forced to work in isolation (i.e., during pandemic).

✗$R_{2436941}$ ***Lack of motivation.*** "*How do you go forward with a project you're stuck on and you can't find the motivation to keep going? ... The whole coronavirus lockdown situation isn't helping either for that matter, I feel like I'm going crazy stayin locked inside these four walls all day every day.*"

✗$R_{2445298}$ ***Lack of coding.*** "*I haven't coded for a week which is the longest I've gone without a commit in about 4 years. ... My productivity before COVID-19 was showing me six figures and I had a perfect work ...*"

Around 40% of the discussions around productivity are positive. We observe that the reasons are centered around having less interruptions during work like (1) (2) developers find that working from home helps them to focus more without many distractions. (3) the developers who got to work from office during the pandemic now have less people around them to create noise or to interrupt. We also find that the lower number of people at office during pandemic motivated some developers to work from office, when they were previously more inclined to work from home.

✓$R_{2427155}$ ***Leveraging empty office.*** "*Only 2-3 people show up in the office (out of 38). Finally some peace to write some decent code.*"

✓$R_{2434545}$ ***Office commute.*** "*Now that I have a car, I might quit on the home office and return to the office again. Less distraction. No one will be there but me.*"

Developers also discussed about the trade off of the benefit of doing pair programming at office vs the smaller number of interruptions at home while working alone. According to them, they have more focus while working from home, which to them can be preferable to doing pair programming.

✓$R_{2435436}$ ***Pair programming vs working alone benefits.*** "*It's super useful to be able to just summon someone for a 7 minute pair programming session, but i have a much greater focus at home when I know I won't be interrupted during work hours.*"

3.1.4 Home vs Office Ergonomics

46.9%Negative
9.4%Neutral
43.8%Positive

The setup of work space is important for developers to work properly. In our dataset, we see similar distributions of positive and negative polarity around developer discussions towards home vs office arrangements during pandemic. Some developers considered the work setup at office is inferior to their work setup at home. Others were enthusiastic with their seamless transitioning to mixing office works with household chores while working from home.

✗$R_{2443352}$ ***Cannot zone out of work at home office.*** "*I don't like the work from home setup. Maybe it's the because of the bad working environment. I actually appreciate office space more now. Once, out of office, it was easier to zone out of work mode and I didn't feel this much tired when working in office.*"
However, even those expressing delight at home office environment, acknowledged to have better equipment at office to support work.
✗$R_{2433095}$ ***Missing office equipment and cooking.*** "*[best part of wfh] Absolutely nothing, i have great equipment at the office, ... we have a chef who cooks great food.*"
✓$R_{2427726}$ ***Cook time + save commute time*** "*Remote work for everybody! It's actually great: get to cook my own lunch, saves an hour in commuting.*"

3.1.5 Travels & Daily Commute Issues

45.5%Negative
18.2%Neutral
36.4%Positive

Developers were unhappy due to the sudden cancellations of their travels to a conference or a holiday. In contrast, developers who were doing long commute to work prior to the pandemic, expressed their delights with not being forced to do such commutes anymore.

✗$R_{2427654}$ ***Conference cancellation.*** "*The local commiccon, linux-days and my working-period at a location on the other side of Germany got canceled. My complete weekend just got annihilated.*"
✓$R_{2426905}$ ***Long commute time.*** "*My commute takes place not only on public transit, but on the train .... So I will probably start working from home this week.*"

Summary of Topics Related to Workplace & Professional Aspects. *The five topics under this category were found in around two thirds of all posts in our dataset (mostly on teleworking). The discussions are mostly negative, e.g., developers found it overwhelming to handle family and office responsibilities from within the confined space of their home. Overall, developers reported to have 1. tensions/unhappiness due to the elevated level of monitoring and communication with their managers, 2. missed the rich social interactions they used to share with their coworkers, 3. increased level interruptions from family members while working from home, 4. oss of productivity while working in isolation due to lack of motivation,* but were happy with being able to easily transition between work and house chores (e.g., cooking) while working from home.

3.2 Personal and Family Wellbeing

43.9%Negative
20.9%Neutral
35.2%Positive

Four topics belong to the category of personal and family wellbeing. Together, the topics are discussed in 410 rants, i.e., around 49% of the rants. The wellbeing developers not only depends on their professional life, but also their personal and family life. The pandemic has blurred the lines between professional and personal time in the daily lives of developers. We observed multi-faceted discussions from the developers on how this new normality in their life has influenced the wellbeing of their personal and family wellbeing along following topics: usage of social media, movies and games (i.e., entertainment) during pandemic, exercising of health and safety measures, balancing between work and life while doing domestic chores, staying connected with family and friends, and making progress on professional responsibilities during pandemic. Around 44% of such discussions contained negative polarity and 22% contained positive polarity. We discuss the topics below.

3.2.1 Entertainment During Pandemic

26.5%Negative
54.4%Neutral
19.0%Positive

About one third of the discussions in the personal and family wellbeing category are related to developers way of relaxing while quarantined at home. We did not find any discussions of developers going outside to have fun. This is not given that the developers followed rules of staying at home during the pandemic. However, due to the developers being at home during the pandemic, their options for relaxation were limited to mostly watching movies or TVs, listening to music, reading books, and playing video games. With less control on time on when to work and when to relax, Developers discussed their difficulty of staying focused at work while fighting the urge to play games.

✗ $R_{2433414}$ ***Collaboration problem with coworker + Gaming distractions.*** "*I'm not a fan. Harder to collaborate and discuss things with coworkers. I'm constantly fighting the urge to turn towards my gaming pc and start playing something.*"

Developers discussed the positive impact of listening to music to stay focused at work. Some developers also shared dedicated music playlists that combined their favorite gaming music with traditional music.

✓$R_{2455598}$ ***Listening music.*** "*I started chilling and coding with this new lofi genre. I might be late to discover this genre but this is an awesome man. I mixed that with the pokemon games that I used to love so much and then I discovered this.*"

Given that devRant allows developers to share their joy and frustrations at work and life, developers also use the devRant platform to exchange jokes/memes during the pandemic. While some of the jokes are neutral polarity, others can have non-neutral polarity.

$R_{2449277}$ ***Corona joke.*** "*Corona should have started in vegas. Because you know, whatever happens in vegas*"

✗$R_{2438154}$ ***Quarantine joke.*** "*15yrs ago I used to quarantine viruses. Now a virus is quarantining me.*"

3.2.2 Health and Safety Concerns

58.5%Negative
28.3%Neutral
13.2%Positive

The pandemic has caused concerns among the developers in our dataset related to diverse health and safety matters. While concerns about physical health are prevalent and understandably so due to the pandemic, developers also frequently referred to their mental health problems that they experienced due to increased social isolation.

✗$R_{2438458}$ ***Physical pain.*** "*I'm literally in pain right now and not a thing I can do ... I cant do weed because my backup plan if I fail at coding is the military.* "

✗$R_{2438651}$ ***Live alone + Isolation problem.***"*With home isolation and remote working due to COVIV19 how do you people who live alone deal with being alone with your thoughts for 8 hours*"

✗$R_{2433938}$ ***Isolation struggle.*** "*It was fun to stay home last week, this week the isolation is starting to get to me.* "

The mental health issues due to isolation and increased social tensions due to pandemic are more concerning for developers who are already suffering from mental problems. A developer cited her ongoing battle with anxiety and how the pandemic and social isolation has exacerbated it.

✗$R_{2432708}$ ***Extreme anxiety.*** "*I'm not afraid of quarantine because I work from home for many years. But I do that only because I have an extreme anxiety and some other problems where I can basically faint if there's just more than 5 people in a rooms. And that COVID hysteria makes me anxious even at home to the degree of paralysis. I can't do even simple things in that state and productive at 20% at best.*"

The drop in productivity among the developers was also attributed to mental issues that emerged or worsened due to the pandemic and working from home.

Loneliness is identified as a major concern for developers during COVID-19 according to a recent survey (2020). Physical and mental health are among the top concerns during the COVID-19 pandemic according to another survey (2020). Admirably, we also found the developers in devRant to help each other fight the loneliness and social isolation by recommending online chat tools and by engaging in chats with each other.

✓$R_{2432475}$ ***Online chat to address loneliness.*** "*You're under lockdown? Lonely? Time for good old* https://chatroulette.com/"

3.2.3 Connection w/Family & Friends

56.9%Negative
17.2%Neutral
25.9%Positive

The pandemic and restrictions on movement have caused problems for everyone to stay connected with his/her friends and families, who are not living with him/her. Developers in our dataset also shared similar issues. Interestingly, developers also cited their state of isolation as reasons to reconnect with their family members.

✗$R_{2437976}$ ***Family re-connection.*** "*Day 8 in isolation. Im lonely.. My brother calls me. I haven't talked to my brother in a long time ... It sucks to be lonely in my tiny little apartment so I actually Skyped with him today.*"

While long distance relationship can be challenging, developers were expressed optimisms that they are looking forward to spending new trip with their long-distance partners once the pandemic is over.

✓$R_{2449921}$ ***Long distance relationship.*** "*Was chatting with my long distance gf today, and sad that we had to cancel our Easter trip due to coronavirus. She cheered me up and we ended up talking about what we want to do once the pandemic is over.*"

However, developers shared their problems with keeping dates due to the sudden shutdown of everything due to the lockdown.

✗$R_{2439637}$ ***Trouble with dates.*** "*I managed to get 2 dates with 2 different girls for next weekend. And now, Australia is going into lockdown: No restaurants and shit.*"

Developers also expressed their sadness at their family members who did not appreciate their working from home and were ignorant of the lockdown restrictions.

✗$R_{2450317}$ ***Lack of family appreciation towards telework.*** "*I hate this work from home with your family around. You're always in front of the computer, go workout, go socialize, its family time. What part of work from home you don't understand.* "

Finally, developers appreciated the devRant platform to help them find new friends in devRant, whom they found to be respectful, helpful and joyful. This welcoming nature of devRant platform, where developers can share both their technical, social and personal problems, is in complete contrast of Stack Overflow, the most popular community for technical communication among developers (Hanlon 2018).

✓$R_{2456910}$ ***devRant community appreciation.*** "*I'm quite new to devRant, but it's really growing on me. I found a respectful, helpful and joyful community and I'm just glad to have found it in this difficult period of coronavirus.*"

3.2.4 Work Life Balance

45.1%Negative
15.7%Neutral
39.2%Positive

In our dataset, we find that the sudden shift towards working from home, the lockdown as well as the closure of schools have created challenges for working families to find a balance between work and life. We find that developers are facing diverse problems like having more workload at home while getting increased demands from bosses at work.

✗$R_{2451333}$ ***More workload at home.*** "*I guess most of us are working from home due to COVID-19 outbreak. For me hell lot of work .. Like in office I can be free at time and have help too.. But now at home hardly have time for lunch, tea breaks etc. I know Work From Home feels good . but I am not feeling it good for too long :(..*"

Given almost everyone is encouraged to remotely over internet during the pandemic, the maintenance of the technical infrastructure has become a priority. The IT professionals in charge of keeping the networks up and working are facing increased workload.

✗$R_{2430482}$ ***Increased urgent work.*** "*You guys work from home because of coronavirus? Me on the other hand, have to work on weekend on my desk to finish an urgent project, it's for the ministry of education (who closed all schools and launched an online courses) to monitor the effectiveness of the new platform and fix some bugs on it.*"

Some developers who are studying part-time while also working are now finding that the demands from both from their Academic and Industrial bosses have grown a bit more than before, because they are assuming that the student/developer now has more free time than before.

✗$R_{2452432}$ ***Increased demand from bosses.*** "**Corona Virus Lock-down* -University Prof: "Now You have lots of time to do your projects. from now, you will have 1 project each week" -Boss: "You are at home all day! can you increase your working hours?" -Me: "[expletive] Corona""*"

However, the new normal of working from home has delighted some developers who are introverts and who prefer to avoid much of other human contacts. The pandemic has given them a valid excuse to avoid all such possible distractions. However, even for those developers cooking everyday and deciding on food to eat everyday have become problematic.

✓$R_{2433822}$ ***Joy for introverts.*** "*We Introverts are going to look back to these days, Don't forget to make some memories..... No one is asking to go out, Employers are offering work from home, to many of us it's the same old same old, in the mean time I wish y'all the best time...*"

✗$R_{2437804}$ ***Keeping sanity during lockdown.*** "*So, those of you who have been in quarantine for more than a week, how are you keeping your sanity? I like my independence, but goddamn this feels a lot like being in luxury solitary confinement. Plus, I have to cook for myself.*"

✓$R_{2437274}$ ***Food.*** "*I am enjoying WFH. But everyday I wonder what to eat?*"

Summary of Topics Related to Personal & Family Wellbeing. *The discussions around personal and family wellbeing revolved around four topics: Access and consumption of entertainment materials during pandemic, health and safety concerns while in lockdown, needs for staying connected with family and friends, and needs for work life balance while working from home. While developers are almost neutral in their leisure time spending, they are worried about their physical and mental health, e.g., the impact of social isolation on their mental health. But they appreciated their networks on friends in the devRant platforms whom they find as joyful and supportive. While finding a balance between work and life seems challenging, we find both positivity and negativity among the developers while working from home and doing household chores.*

3.3 Lockdown Preparedness

52.3%Negative
24.4%Neutral
23.3%Positive

Around one third of the posts contained discussions around developers' preparedness to cope with the pandemic. Most of such discussions are not related to their daily development activities. Instead, the discussions revolved around developers' analysis of the the trends of infection, their fear and anxiety, and their suggestions to each other to prepare for the lockdown. Overall, more than 54% of such discussions contain negative sentiment and only around 26% have positive sentiment in the form of optimism about the future or life. The discussions can broadly be divided in two topics: coping strategies during lockdown and emergency awareness and supplies. We discuss the topics below.

3.3.1 Coping Strategies & Pandemic Trends

53.0%Negative
23.5%Neutral
23.5%Positive

The developers shared their views about pandemic with each other. They were worried about the overall pandemic trends, which reflected on their negative sentiments towards various aspects of their life affected by the lockdown. They were worried about the family members who were still working in office or outside or who were still going to school. Some developers expressed positivity while staying in lockdown. They cited that the situation has forced/motivated them to start/resume a side/new software project. Developers also shared that they would use this time to read books that they otherwise did not have time to finish before.

✓ $R_{2444548}$ ***Side project.*** "*Quarantine finally made me pickup my old projects.*"
✓ $R_{2441848}$ ***COVID-related project.*** "*So I picked up an interesting project to work on. Visit https://minilancer.in to check LIVE stats of coronavirus cases worldwide. I'm using coronavirus API from rapid api*"
✓ $R_{2432408}$ ***Reading books.*** "*So, what's my plan for this unplanned in-house vacation, you ask? Idk. Probably just staying in bed. Maybe bother with finishing all the damn annoying books I've left unread. Yay.*"

Some developers mentioned that they are still going to office, because now their office is less crowded than their home due to most employees working from home.
✗ $R_{2426819}$ ***Still going to office.*** "*So I'm in Italy, close to Milan, the biggest infected zone in the whole country. I'm still going to work as we're in 2 people in the office ... So nothing really changed actually*"

3.3.2 Emergency Awareness and Supplies

52.1%Negative
22.5%Neutral
25.4%Positive

Developers shared excerpt from news articles that are related to the pandemic, as well as the rules of safe social distancing. The discussions about shopping are prevalent and the shortage of supplies in superstores or online sites.

✗$R_{2433008}$ ***Shortage due to panic buying.*** "*Not dev related but this panic buying over COVID19 is putting my family in a hard place, I have 5 kids to feed and there are no slots of home delivery and most things are being sold out.*"

Some developers also reported more desperate situations with their shortage of food and the sudden closure of food stores around them.

✗$R_{2441367}$ ***Supply shortage.*** "*Lockdown Day 1 of 21. Cooking gas ran out. Drinking water is also over. The nearby water vending machine is also not working. Didn't have lunch, already starving even with whatever snacks that was stocked.*"

Developers shared information to stay aware of the emergency situations and to develop software by analyzing data about the COVID-19 infection trends.

✓$R_{2439188}$ ***COVID data analysis app development.*** "*Hey guys is there anything we as devs could do regarding this COVID-19 situation in terms of our technical skills? Like any project or something for making awareness at global or local level, or some status update regarding various things/items that are affected by this pandemic? I am looking for ideas or currently ongoing projects that i could contribute to. Currently my tech stack is limited to java, python , android and a little bit of basic data analysis, but i am fluid enough to learn and contribute.*"

Misinformation and fake news about COVID-19 are prevalent on online social media.[2] Developers in devRant reported that they are also affected by such fake news. We find some discussion from developers about how they are also getting such fake news from other sources like their video game portals. The following developer identifies inaccurate information in his mobile game feed.

✗$R_{2453979}$ ***Fake/Political news.*** "*The pandemic aside, even the type of absurd news messages in the Plague Inc mobile game have become reality. - "President berates reporters for asking 'tough questions' " - "Corona beer stocks dive as result of coincidentally unfortunate brand name" ...*"

A developer replies to this post with another example of fake news he received "*People torch new 5G antenna thinking it propagates the virus.*" Another developer was curious to know of the spread of such fake news in online media "*... I know looooooaaaads of sites with conspiracy theory about this are floating around.. but do you perhaps know where to find some sort of infographics for this? I think I saw one on 9gag or fb, but cannot find it anymore.. I know it's a long shot, but still..*"

Summary of Topics Related to Lockdown Preparedness. *Developers were worried about how the lockdown affected their daily lives. They discussed the possibility of developing software to better support the data analysis on COVID-19 infection trends. Some developers had extra free time due to lockdown and they started to utilize the time by starting/resuming side projects or reading books.*

[2] https://globalnews.ca/news/7876321/covid-19-misinformation-social-media-facebook-instagram/

3.4 Technical Aspects

41.4%Negative
26.3%Neutral
32.3%Positive

Topics in this category discuss issues related to software development (*Development*), technologies (*Technology*), and *Security* A major part of a developers' daily life is to develop software systems. We observed three types of topics related to the various technical aspects that developers discussed while discussing the impact of the pandemic on their daily development activities: development environment and resource access, hardware setup and online site access, and security concerns while working remotely. Around 39% of the discussions around technical aspects are negative, 32% are positive and rest are neutral.

3.4.1 Dev Environment & Resource Access

35.7%Negative
33.9%Neutral
30.4%Positive

The majority (36.4%) of the discussions around developers access to development environment and resource access are neutral. This is because for most developers the transition from office to home for work was not problematic and they reported as such. Around 31.8% reported positive experience. In such cases, the developers also discussed how they can share their computing resources with others to help in COVID-19 research.

✓ $R_{2434191}$ ***Share Computing Resource for COVID Research.*** "*We are devs right? We have cpus and gpus lying around right? We are still alive... right? How about we do our part and utilize our PCs for helping with COVID-19 research.*"

Around 31.8% reported negative experience, with various resources, such as slow internet, access denied to company version control system, having struggle with onboarding to a new code base for new hires while working remotely, and even problems with software documentation and how that affected severely to make progress from home. The developers frequently cited the importance of good software documentation during COVID-19 while working from home, because the experts may not be readily available. Without documentation support, they reported to write bad/faulty code as well as getting totally stuck.

✗ R_{327701} ***Slow Wifi.*** "*When you come 1000kms away from office to home.. and promise to do WFH and the wifi at home is slow... Killing me!! Too many backlogs this sprint*"

✗ $R_{2448996}$ ***Version Control Problem.*** "*Can't git push. because of an "access denied" error message. because I didn't set up my key file properly (with right paths, right format and so on. because I'm working from my home laptop device. because I'm in home office. because Corona*"

✗ $R_{2454917}$ ***New Job + Lack of Documentation.*** "*Started a new role as a front end developer working with React, having a great hope that I will learn from the best with my team, and then ... COVID-19 ... I have to work from home. first task, implement a feature on a react front end build with react boilerplate, first time seeing this repo and dispair quickly took over, there is no documentation except for clone and install, the code is a*

mess, the console is filled with errors and warnings ... I did what I could, my n+1 didn't complain but if I was him i'd fire my ass with no regret"

✗$R_{2438499}$ ***Bad Documentation.*** "*LLVM AND BISON FIX YOUR [expletive] DOCUMENTATIONS. I've been trying the whole quarantine period to make some small Bison and LLVM snippets because I've been planning to make a compiler for my own language. But I haven't been able to make a SINGLE THING WORK because these projects have the WORST DOCUMENTATION I HAVE SEEN IN MY LIFE FOR AN OSS PROJECT. Seriously, no basic references, no tutorials, no nothing. It's as if they are trying to obscure it all! I'm looking for alternatives now.*"

3.4.2 Hardware Setup & Online Site Access

52.2%Negative
25.0%Neutral
22.8%Positive

The sudden shift towards work from home has forced some developers to setup their home internet by themselves. The developers cited problems with the internet router malfunctioning. The greater than normal load on the internet usage and the lack of preparation from the ISPs to tackle such situation was highlighted.

✗$R_{2442182}$ ***Router Malfunctioning.*** "*Tldr: no router, almost not work. Ok I recently moved into a new house, and I signed a contract for an Internet line. Problem is that the router has been sent at the ISP shop, where I was supposed to get it personally. But guess what? COVID emergency happened two days after, and the shop closed.*"

✗$R_{2437251}$ ***Lost Internet + No ISP Support.*** "*We were forced to work from home since our region is under "Enhanced Community Quarantine". I brought my work computer at home so I don't need to set up shit on my personal computer. After 2 days, I lost my internet connection and I can't contact my fucking ISP, their office is closed and their customer service doesn't exist. I am now under No Work No Pay policy. Fucking what the fuck.*"

Many e-commerce sites found it difficult to handle large volume of user transaction during the pandemic. The developers discussed the importance of good software design to improve the speed of e-commerce website.

✗$R_{2442302}$ ***Slow E-commerce Website.*** "*Corona shows that certain webshops were bought up cheaply and can't handle large loads. The fact that my shopping cart constantly crashes, the website itself crashes, flips between logged in and logged out, state is constantly corrupted and.. every so now and then I get 500 server errors, yeah, clear signs of no load balancing policy.*"

The developers experienced glitches with the videos and audios transmitted over the video conferencing apps.

✗$R_{2431676}$ ***Glitches in Video Conferencing.*** "*So i guess Zoom and other video conferencing applications are feeling the pressure! I am currently taking an online class for my bootcamp, and the audio and video are both so glitchy!*"

However, the developers also appreciated the important roles the IT professionals have played to facilitate remote work suddenly.

✓$R_{2445937}$ ***IT Appreciation.*** "*Salute to doctors to fighting to corona. ... but also Salute to IT to maintaining balance in economy!!*"

3.4.3 Secure Access Concerns

50.0%Negative
27.3%Neutral
22.7%Positive

Developers needed to ensure that they follow the proper security principles before granted access to internal company resources. They were happy when they managed to setup the gateway system properly. However, several developers reported problems using VPN (Virtual Private Network) and two factor authentication.

✓$R_{2086420}$ ***Secure Gateway.*** "*So today's the day. We've now successfully installed four Ubiquity AP's with a Ubiquity Security Gateway onto a 1000/1000 fiber line.*"
✗$R_{2433304}$ ***Trouble with VPN.*** "*Anybody having trouble with work VPNs during the health crisis? I can't imagine most have ever had this kind of test before.*"
✗$R_{2447609}$ ***Two Factor Authentication.*** "*How mush longer do I have to sign into every app I use with 2FA? Not being on the company network is annoying...*"

Summary of Topics Related to Technical Aspects. *Compared to the topics from other categories, the developers are relatively more positive towards topics related to technical aspects. They appreciated the important role played by the IT professionals to facilitate the remote working environment in such a short notice. However, they cited the following problems: 1. The access permission to company development environment (e.g., version control). 2. The loss of internet connection and the lack of support from ISPs, 3. Their problems with router setup and VPNs for secure access, 4. Their problems with online tools and websites in general, and 5. The lack of documentation when team members are not available to answer questions.*

3.5 Financial Concerns

65.8%Negative
18.3%Neutral
15.8%Positive

Although the technology sector has been resilient to job losses during the pandemic, major companies laid of substantial number of workers (Coronavirus Unemployment 2020; Coronavirus Layoffs Remake Silicon Valley Job Market 2020; Coronavirus Impact 2020). Indeed, developers in our dataset expressed their financial concerns around two topics: developers worries about jobs uncertainty and personal finance and the state of the business and marketing they are part of or they are exposed to.

3.5.1 Jobs Uncertainty & Personal Finance

65.3%Negative
15.8%Neutral
18.8%Positive

Some developers reported to have lost jobs due to the pandemic. While some of them could rely on personal side projects to survive during the pandemic, others reported that they do not have any such personal or family saving to survive after their job loss.

✗$R_{2458117}$ ***Job loss & reliance on side projects to survive.*** "*Lost my main job due to corona. All I have left now is my few personal gaming projects which generate decent money (usually around 2k euro a month but during corona jumped 3x 4x). I am trying my best to take care of my projects now because its all whats left. Last 2 weeks spent applying for jobs and did really well in 2 of them however didn't receive an offer because they canceled recruitment process all together. Meanwhile my gf lost her job and spends most of time in home.*"
✗$R_{2442534}$ ***Job Loss & no saving*** "*Got sacked with no savings and safety nets like family to rely on. The industry in Australia is fickle at the best of times.. Now I'm well fucked.*"
✗$R_{2433818}$ ***Pay cut Due to Remote Work.*** "*My [expletive] company just decided that anyone who wants to work from home because of the Corona scare will get a 50% pay cut. Even if there's zero drop in efficiency. How illegal is this [expletive]?*"

Freelance developers also reported to have less works due to less number of requests coming from their clients.

✗$R_{2433031}$ ***Less freelance works.*** "*I'm worried, as I'm sure many of you are about COVID 19 and work drying up. I can work from home but who's gonna want to get a new site or app done now with so much uncertainty!*"
✗$R_{2431553}$ ***Reduced work hours due to less client.*** "*Just as the virus started, shitton of companies just canceled our services. We already started dropping the price and I will probably have my week reduced to 10h (with an accordingly lower pay).*"

Developers looking for jobs during the pandemic were not optimistic with the job interviews that were scheduled during the pandemic. They reported to have missed the chance to start/sign a new job offer due to the pandemic.

✗$R_{2438940}$ ***Job interviews.*** "*Whats the point in interviewing now? My country still has quarantine until end of March. Quarantine might be extended and nobody knows how many weeks or months it will take for things to go back to normal. I already did 4-5 interviews with technical tasks and now will have to wait for a response which might take months. After that waiting most likely I will have to do technical interviews once again. Its as if they are trying to give something to do for their internal HR staff just so HR would keep their jobs. What a waste of time.*"
✗$R_{2440448}$ ***Job offer postponed.*** "*Just my luck. I was supposed to sign a new contract last week and get paid 2x more than now + get a lot of benefits. The day before, obviously, they just HAD to stop signing contracts with new people because of COVID.*"

Developers also discussed the new job opportunities at the USA due to the shortage of COBOL programmers to handle the state unemployment claim system.

✓$R_{2452241}$ ***Job opportunities.*** "*So as millions of Americans file for unemployment the state of New Jersey is begging for help from COBOL programmers to keep their 40+ year old unemployment systems running. Who knows COBOL here?*"

However, developers who had a stable job reported to have higher saving due to a reduction in their regular activities while working from home.

✓ $R_{2437783}$ ***Saving while working from home.*** "*I don't like WFH too much but I'm saving a lot of money working from my house*".

3.5.2 Business & Marketing

59.1%Negative
22.7%Neutral
18.2%Positive

Developers ranted about the negative impact of COVID-19 on businesses they have founded or the consulting firm they are part of. For the consulting firms, the negative impacts come due to the retail store clients they have who have suffered the most impact due to the lockdown.

✗ $R_{2433930}$ ***Less work due to customer close down.*** "*Well, will see where the future brings my company. Many of our customers had to close down. They told us that we might have to work much less.*"
✗ $R_{2436871}$ ***Consulting work shutdown due to customer store close down.*** "*My project was closed down yesterday due to growing concerns about the global pandemic. I can somewhat understand the reasoning behind this action. Context: I work for a very large consulting firm that does software development and systems consultancy. The client has a business model that is fully reliant on in-store profit. All of the stores are closed or empty.* "

The developers working in/with the marketing department of companies felt that they are the first one to be dropped due to the pandemic, even though the revenues of their company mostly come from advertising.

✗ $R_{2453844}$ ***Impact on marketing department.*** "*Global pandemic is now at least for a month so it's a good time to start reading about first market movements..Marketing is always dropped first and above companies revenues are mostly from advertising*".

Summary of Topics Related to Financial Concerns. *Developers reported to have lost jobs due to the pandemic with some having no saving to fallback during the pandemic. Developers even in large consulting firms reported to have work hours and pay reduced due to he close down of their clients. The developers were not optimistic that interviews during the pandemic will lead them to a new a job. However, developers who had a stable job during the pandemic reported to have saved more due to a reduction in their normal regular costs, such as transport. Depending on the types of development jobs or departments a developer works for, the impact of pandemic differs. For example, marketing department may be more negatively impacted during the pandemic due to client close down.*

3.6 Education & Societal Concerns

53.1%Negative
27.4%Neutral
19.5%Positive

Personal growth is important for developers through education. As such, we see discussions on the largely negative impact of COVID-19 lockdown on bootcamps educational

degrees, and certification exams. The socio-political aspects of developers' country of residence also came into discussion, as well as developers' delights on the positive impacts on the environment. We discuss the three topics below.

3.6.1 Education

45.3%Negative
26.4%Neutral
28.3%Positive

We observed three types of education related discussions: bootcamps and certification exams, and university courses. Around 47% of the discussions are negative and 29% are positive. The negative sentiments were mainly due to the postponement of their professional courses/exams and the anxieties the developers have about sending their children to schools during the early days of pandemic.

For bootcamps, while the courses are shifted online, the courses are condensed in a short time. The developers felt that this change is not helpful for proper learning and to get a job.

✗ $R_{2444749}$ ***Impact of developers' bootcamp.*** "*I've been doing a bootcamp in my country, learned the basics with c#, did some small projects but nothing too impressive. I started also web I'm that bootcamp, learned the basics of html css and js.. then all this corona madness started and yes, we still have classes online but less times a week and it's way harder. I'm feeling a little lost with what to learn, how and scared I might never be able to get a job.*"

Many of the certification exams are postponed, leaving developers, who were looking for new jobs based on the completion of the certification, stuck with their career move or job seeking.

✗ $R_{2440448}$ ***Postponement of certification exam.*** "*Also my engineers exam is postponed indefinitely. They are thinking about making it online, which would be awesome, but again - it was supposed to be last week. A lot of stress and time wasted.*"

The science teachers also joined the discussions and expressed their concerns on conducting a course fully over online, especially for lab courses where in-person interactions are crucial to teach science materials and to convey the messages.

✗ $R_{2430200}$ ***Online teaching problems.*** "*My job is as a teacher, but my school just canceled all in-person classes for the next two weeks, so I will have to teach over phone or Zoom. But I teach a science class and I am in the middle of a set of labs!! How are my students supposed to do lab work in groups over Zoom?!?!*"

3.6.2 Law & Politics

69.2%Negative
15.4%Neutral
15.4%Positive

The pandemic has prompted the Governments to take unprecedented actions to support the wellbeing of the people. The flexible work from home policy for parents was appreciated and highlighted by the developers.

✓ $R_{2430571}$ ***Flexible WFH.*** "*We have been strongly advised to be working from home until further notice. Schools are closed, so if employees have have who are now to stay at home rather than at school AND if WFH is going to be too much of a trouble, these employees can either take vacation days OR get a med cert from a doctor and stay at*

home w/o having to work (yes, considering the situation our govmt allows legal slacking for parents)."

However, developers also discussed when the Government applied its power to force the IT department of a news company to delete a negative information about Government action.

✗$R_{2449842}$ ***IT in legal issues.*** "*During this time of pandemic all around the world, our government tried to do corruption in the import of medicines for corona victims. An online news portal reported this and it was starting to get some heat. Then a major IT company of my country [The one who developed the news portal] deleted that specific news from the backdoor login. That news was a public record.*"

Some developers also reported that they were instructed to return home country to work during the pandemic. According to a developer, the instruction was given after the pandemic started and after the initial promise of doing the opposite. The inconsistency in instruction denotes the uncertainty of both the management and the developers to handle a pandemic like COVID-19. In case of the above developer, he had to fly a longer distance than usual due to the flying restrictions that were imposed across the world during the pandemic, costing him twice than the normal amount in plane fares.

✗$R_{2434355}$ ***Return to home from job.*** "*I've been given notice that I need to return to my home country to work following this coronavirus. This was of course after being promised that wouldn't happen. It costs me twice as little to fly THREE TIMES the distance than it does to fly to my home country.*"

3.6.3 Environment

10.0%Negative
0.0%Neutral
90.0%Positive

Developers were overwhelmingly appreciative the positive impact of work from home and lockdown their surrounding environment. They mentioned the clean air and quiet night, the reduction in pollution. Some developers even discussed the idea of creating sites to collect petition on enforcing periodic lockdowns to support environment, even after the COVID-19 pandemic is over.

✓$R_{2454472}$ ***Clean air and quiet night.*** "*I really enjoy the clean fresh pollution free air and the quietness at my night walks.*"

✓$R_{2434362}$ ***Avoid pollution by WFH.*** "*My fav part of working from home is that I don't have to inhale the pollution and dust of the city.*"

✓$R_{2439966}$ ***Petition for periodic lockdown to reduce pollution.*** "*Forbes study shows that there has been a drastic reduction in pollution levels in [country] during the lockdown period due to Coronavirus outbreak. I think it can be a pretty good idea to lockdown the world periodically to heal the planet. Here's a petition for the same. If you support the cause, please sign and share at ...*"

Summary of Topics Related to Education & Societal Concerns. *Developers discussed the negative impact of pandemic and lockdown on their bootcamps, certification exams and their studies at the Universities. Developers appreciated when their Government allowed flexible work from home policies for the working parents and the positive impact of lockdown on their surrounding environment.*

3.7 Co-occurrences of Topic Categories

The six topic categories are found 1,767 times in our dataset. Two topic categories co-occur in a post if the post is labeled with both of the topic categories. In Table 4, we show the frequency of co-occurrences between the categories in our dataset. For each topic category, there are two rows in Table 4. The first row (#) under the topic category 'Workplace & Professional Aspects' shows the total number of times two topic categories are found together in our dataset, i.e., a given post is labeled by both topic categories. For example, the two topic categories (Workplace & Professional Aspects, Personal & Family Well-being) co-occurred 230 times. The second row (%) under the topic category 'Workplace & Professional Aspects' shows the fraction of times the topic category was found in our dataset and the total number of times it is co-occurred with each of the other topic categories. For example, the topic category 'Workplace & Professional Aspects' was found total 580 times, out of which it co-occurred 230 times with the category 'Personal & Family Well-being', i.e., (ratio = 40%). Note that while the co-occurrences frequency (i.e., #) is one single value between any topic categories, we have two ratios (one per category). For example, the category 'Personal & Family Well-being' is found total 362 times in our dataset, out which it is co-occurred 230 times with the category Workplace & Professional Aspects (ratio = 64%). The number in bracket besides a topic category shows the total number of occurrences of the category in our dataset (which is used in the % calculation).

The topic category Workplace & Professional Aspects shows the maximum number of co-occurrences with three out of the five categories (one tied to the category Personal and Family Wellbeing). Among the posts that are common between this category and other topic categories, the two topics 'Telework' and 'Coworker/Manager Relationships' are found the most across all pairs (i.e., co-occurred category pairs). For example, the following post is labeled as both topic categories " *#TheCoronaEffect. Before Corona: (Work From Office). Boss: Let's have a call. Me: Sure, allow me some time I am assisting the team on a new feature in the app.Boss: Ok, ping me as you get free. Now: (Work From Home). Boss: ***Calls for the 15th time in a day...*** Me: (With Bleeding Ears) Yes sir, am here...! (Having to pick*

Table 4 co-occurrences of the topic categories in our dataset

↓ Topic category →		WP	PW	LP	TA	FC	EC
Workplace & Professional	#		230	148	188	108	94
Aspects (WP) (580)	%		40%	26%	32%	19%	16%
Personal & Family	#	230		238	184	46	46
Wellbeing (PW) (362)	%	64%		66%	51%	13%	13%
Lockdown	#	148	238		126	38	88
Preparedness (LP) (305)	%	49%	78%		41%	12%	29%
Technical	#	188	184	126		38	38
Aspects (TA) (282)	%	67%	65%	45%		13%	13%
Financial	#	108	108	38	38		28
Concerns (FC) (123)	%	88%	88%	31%	31%		23%
Education &	#	94	46	88	38	28	
Societal Concers (EC) (115)	%	82%	40%	77%	33%	24%	

*up every single time as he knows you've got nowhere to go 'coz the whole city is in Lock-Down). Boss: ***Talks for another 1 hour with screen share***. My Boss is a bigger threat to my health than Corona now!!! #GoCoronaGo"*" $R_{2439836}$.

The category Personal and Family Wellbeing shows the maximum number of co-occurrences with the category 'Lockdown Preparedness' among all categories (238 times). Several topic categories show higher-degrees of co-occurrences with the three most frequent topic categories (Workplace & Professional Aspects, Personal & Family Wellbeing, and Lockdown Preparedness). For example, the following post is labeled as categories like Lockdown Preparedness, Workplace & Professional Aspects, and Financial Concerns: "*I haven't coded for a week which is the longest I've gone without a commit in about 4 years. ... My productivity before COVID-19 was showing me six figures and I had a perfect work:life balance. ... I just wish I could help some of my friends who have lost fucking everything ....*" $R_{2445298}$

The two lowest frequent categories (Financial Concerns, Educational and Societal Concerns) each shows more than 80% co-occurrences with the most frequent category Workplace and Professional Aspects. This is mainly because around two thirds of the posts in our dataset are labeled with the topics related to the category Workplace and Professional Aspects. While the category Financial Concerns shows similar co-occurrences ratio with the category Personal and Family Well-being, the category Educational Concerns shows the second most co-occurrences ratio with the category Lockdown Preparedness. This means that developers who cited their concerns about their learning (to advance their career) and societal issues (e.g., environmental) discussed those mainly along with their discussions related to pandemic preparedness and workplace and professional aspects.

4 Discussion

We first compare the findings from our study with related work in SE on COVID-19 (Section 4.1). We then discuss the implication of our study findings in Section 4.2.

4.1 Our Study Findings Compared to COVID-19 Related Studies in SE

In Table 5, we summarize the key findings from our study and compare our findings with the COVID-19 studies for SE. A detailed overview of the related work can be found in Section 6.1. The table has three columns. The first column 'Topic' outlines one of the six major topic categories we found in our study and discussed in Section 3. The second column 'Our Findings' summarizes key findings from our study along a topic category. The last column compares our findings with the related work. We compare the findings with related work based on our answers to our two research questions, i.e., socio-technical aspects of life that discussed by developers that are attributed to COVID-19 (RQ1) and the sentiments expressed by the developers towards the aspects (RQ2). In Section 3, we answered the two research questions together by analyzing and grouping developers' discussions based on the aspects discussed and sentiments expressed.

In summary, our study confirms the following key findings from the current SE research papers in SE on COVID-19.

1. Developers reported to have a loss of productivity and wellbeing during COVID-19. While our study used data from the early few months of COVID-19, the findings at

Table 5 Comparison of our study findings with related COVID-19 research findings

Topic	Our findings	Comparison with previous findings
Workplace & Professional Aspects	The sudden shift towards remote work was considered mostly disruptive by the developers. Developers were unhappy with increased micromangement and monitoring of their work from home. Developers reported that they are less productive while working in isolation at home and they miss the rich in-person interactions with their coworkers.	Our observation of a decline in productivity and wellbeing is consistent with current qualitative and survey-based study findings (Ralph et al. 2020; Russo et al. 2021a). We also find that social isolation and lack of motivation are key factors for the loss of productivity. Ralph et al. (2020) found that there is no correlation between what developers believe would help and what them. We also find that developers employers are actually doing to support are not happy with micromanagement and increased monitoring during COVID-19. Similar to previous papers (Wang et al. 2021b), we find that developers miss the social in-personal interaction with their co-workers but some are happy with work from home.
Personal & Family Wellbeing	While developers are almost neutral in their leisure time spending, they are worried about their physical and mental health. They appreciated their friends in the social platforms. We find both positivity and negativity while working from home and doing household chores.	
Technical Aspects	Developers appreciated the IT professionals to facilitate the remote working environment in such a short notice. However, the developers cited the following problems: access permission to resources behind company firewalls, modem setup, Internet and wifi connectivity and lack of support from ISPs, and lack of documentation on software products when team members are not available to answer to questions.	The difficulty of setting up multiple work environments is observed by Wang et al. (2021b) at Microsoft China, where developers worked in a hybrid mode in the later phases of COVID-19. Rodeghero et al. (2021) find that the onboarding of new hires at Microsoft via zoom/teams cannot offer the same social impact as in-person communication. Unlike them, our results are based on developers from any domain/company and region.
Lockdown Preparedness	Developers discussed the possibility of developing data analytics software to better COVID-19 awareness. Some developers reported to start/resume side projects during the extra free time they had due to working from home. While the majority of discussions around disaster preparedness are negative, developers also	The study of NicCanna et al. (2021) at Ocuco Ltd, a globally distributed company finds that the company had little difficulty to cope with remote work during COVID-19, because it was already mostly remote since 2016 and it was following a Scaled Agile Framework (SAFe). Ozkaya (Ozkaya 2020) argues that

Table 5 (continued)

Topic	Our findings	Comparison with previous findings
	expressed their willingness to utilize their skills to better understand the pandemic and to stay aware.	organizations that practiced agile development before the pandemic fared better during the pandemic. We did not observe discussions of agile development in our study.
Financial Concerns	Developers reported to have lost jobs or loss of income due to the pandemic with some having no saving to fallback. Developers who had a stable job reported to have saved more due to a reduction in their transportation costs.	We do not find any related research that offered direct evidence from developers of job loss or loss of income due to the pandemic. Ralph et al. (2020) found that job assurance during pandemic is helpful for developers' wellbeing.
Education & Societal Concerns	Developers reported the negative impact of lockdown on their bootcamps, certification exams and their studies. Developers appreciated when their Government allowed flexible work from home policies for the working parents and the positive impact of lockdown on their surrounding environment.	We are aware of no research that offered direct evidence from developers on their personal development during the COVID-19. The wellbeing of a developer can be positively correlated to his/her personal development. Unlike previous research, we also see discussions about society and environment from developers.

Microsoft on longitudinal data show that the loss of productivity is more prominent during the later phases of COVID-19.
2. Developers were not happy with micromanagement or increased monitoring/reporting to bosses while working from home during the pandemic.
3. Developers reported to have a loss of motivation while working in isolation.
4. Developers were happy with the lower amount of interruptions from co-workers while working remotely, but were now experiencing more interruptions from their family members while working from home.

In addition, our study adds the following new insights to the body of software engineering literature related to developers' lives during COVID-19:

1. We find that developers' productivity are also affected by their problems to get access to their company resources behind firewalls, lack of Internet connections or proper wifi, and various other technical issues.
2. We report discussions from developers who lost their jobs due to the pandemic, leaving them with little or no savings to fallback to.
3. We report discussions from developers on the impact of COVID-19 on their overall personal improvement, such as less effective bootcamps, postponed exams, and so on.

As we noted before, unlike previous research, we also offer evidence of sentiments expressed towards each of the above insights. Given we also analyze the sentiments expressed by developers towards the aspects, our research offered the following new insights based on the analysis of sentiments.

1. For each aspect we observed, we report the sentiments expressed by developers towards the aspects. The insights on sentiments helped us understand that developers are more negative towards aspects. We observed that out of the six aspect categories, the negative polarity accounted for more than 50% of the discussions for four categories: Workplace & Professional Aspects (53.6%), Lockdown Preparedness (52.2%), Financial Concerns (65.8%), and Education and societal concerns (53.1%).
2. Despite majority of discussions having negativity towards the COVID-19 situations, we also find positivity among developers on various aspects, such as environment, their personal free time, reduced/no commute time, more time with family, and so on.
3. We also see that developers discussed positively to help others during the pandemic by leveraging their skills (e.g., build awareness software) and their computing resources (e.g, GPU to process large pandemic models).

4.2 Implications of Findings

The findings from our study can guide the following major stakeholders in software engineering: 1. *Software organizations* to guide them to better support their employees during a pandemic like COVID-19, 2. *Software practitioners* to find positivity from other developers on their dealings with COVID-19 crisis, and 3. *Software Engineering Researchers* to study new and innovative ways of addressing developers' problems during a pandemic like COVID-19. We discuss the implications below.

Software Organizations. In Fig. 5, we show a bubble chart as a trade off between the popularity of the six topic categories and the negativity ratios in the six categories in our dataset. The popularity for each topic category is calculated by taking into account all the posts where the topics in the category were found in our dataset and then by

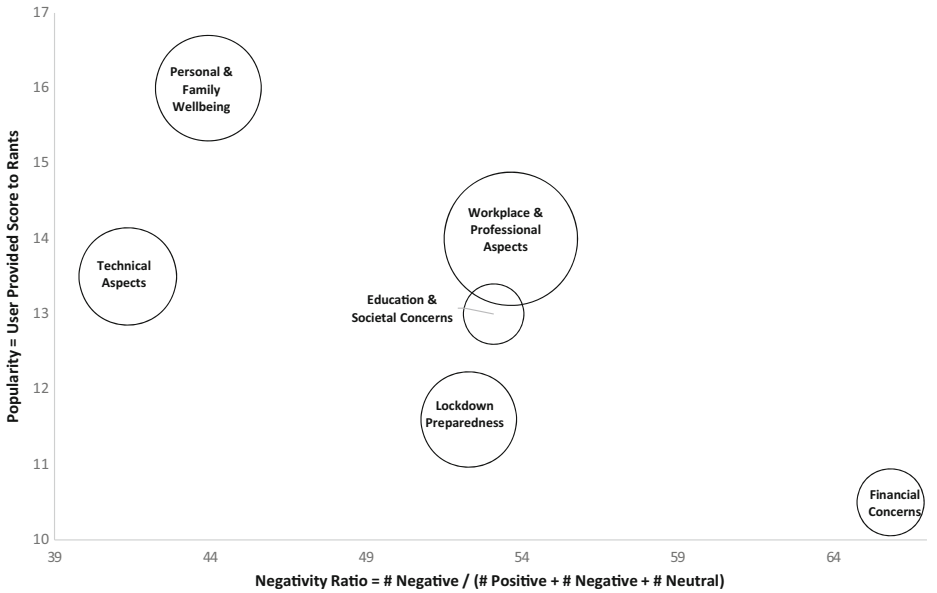

Fig. 5 Trade off COVID related topic categories by negativity/popularity

computing the average of the scores to the posts. Recall that in devRant developers can upvote or downvote a post. A score for each post is calculated by taking the difference between upvote and downvote. An upvote is denoted by a '+' sign and a downvote is denoted by a '−' sign in devRant. An upvotes from a developer to a post means that the developer likes/supports/agrees with the post content. A downvote denotes otherwise (e.g., a disagreement). Thus, the notion of upvotes and downvotes in devRant is similar to other online developer platforms like Stack Overflow (SO). Therefore, similar to SO, devRant also calculates the overall score of a post using the following equation (#upvote - #downvote), which then similar to SO can be used to assess the popularity of a post in devRant. In Fig. 5, the negativity ratio for each topic is calculated as the ratio of all negative discussions for a topic divided by all negative + positive + neutral discussions for the topic in our dataset. The size each bubble for a category is the total number distinct posts where the topics of the category were found in our dataset. The bigger the size of a bubble representing a category, the more frequently it is found in our dataset.

Based on the average score, the category 'Personal and Family Wellbeing' is the most popular, followed by the category 'Workplace and Professional Aspects'. Both of these categories discuss matters related to the productivity and wellbeing of software developers. This means that the discussions related to the two categories are appreciated by software developers, but they were largely negative while expressing their situations. As we noted in Sections 3.1 and 3.2, software developers expressed their unhappiness with regards to micromanagement and increased remote monitoring. They also cited such actions as threats to their physical and mental wellbeing. Previously, Ralph et al. (2020) also highlighted the negative impact of such micromanagement on the developers during the pandemic. Organizations can adopt more understanding and flexible working policy for software developers during a pandemic like COVID-19.

In Section 3.4, we also find that developers working home have experienced technical problems, including most trivial ones, such as connectivity to company resources and lack of software documentation. Companies can increase their efforts to resolve such issues, so that work from home can become more readily adopted by employees whenever needed. In particular, out study findings are based on the data from developer discussions in the early months of COVID-19, i.e., January to April 2020. During these months, the almost entire working process in software companies had changed from in-person to fully-remote. The rapid change in working environment, as we noted in Section 3, has created diverse problems in the life of software developers (e.g., relationship with managers and co-workers). Software companies can take note of the issues we reported (e.g., remote micro-management) and can devise better ways quickly to handle remote working, if a pandemic situation like COVID-19 arises in near future.

In Section 3.7, we showed that the six topic categories observed in our study are often not discussed in silos. Out of 825 posts 580 (70%) contained discussions about 'Workplace and Professional Aspects'. Around 16–40% of those posts also contained discussions about the other five aspect categories like 'Personal and Family Wellbeing' (40%), Technical Aspects (32%), Lockdown Preparedness (32%), Financial Concerns (19%), and Environmental and Societal Concerns (16%). This observation shows that organizations need to adopt a multi-faceted approach to improve the lives of the software developers, while focusing on concerns discussed under 'Workplace and Professional Aspects'. Indeed, with the continued trend towards work from home, the line between personal and professional responsibilities becomes blurred and complicated. Software organizations need to adopt strategies by focusing on their professional, personal, and family wellbeing. For example,

we find evidence that developers in devRant like how they supported each other by listening to their problems and joys. Thus, organizations may also support developers to address their non-professional concerns easily and quickly, e.g., by offering counseling and/or by creating virtual communities, etc.

Software Practitioners. The COVID-19 pandemic has forced people across the globe to suddenly move to an online only system for work, shop, play, and everything related to meet the necessities of life. The increase in popularity of online websites like e-commerce sites has put significant load on the sites. As developers in our dataset have discussed, many of the sites were not designed to meet such demand. According to one developer in our dataset: "*Corona shows that certain webshops were bought up cheaply and can't handle large loads. The fact that my shopping cart constantly crashes, the website itself crashes, flips between logged in and logged out, state is constantly corrupted and.. every so now and then I get 500 server errors, yeah, clear signs of no load balancing policy.*" $R_{2442302}$. According to the developers participating in the discussions, this was a wake up call for software practitioners to properly design software sites, so that they can meet such huge demand next time. Performance, scalability, and good design are all fundamental aspects in software engineering, yet software developers may not have enough expertise to apply those in their work. A pandemic like COVID-19 is more like a 'black swan' event that can disrupt our normal work life balance. However, this pandemic has shown our increased reliance on technology to support our daily life and critical national activities. This reliance is unlikely to decrease in the near future. Therefore, software practitioners can give more efforts to learn and to apply scalable and secure software design and development. Educational contents can be developed to support developers in their learning. Support and policy at the organizational level can also help, e.g., offering dedicated time and organization of hackathons to create scalable and secure software systems.

Developers in our dataset also complained about their hardship of getting access to the secure network inside their companies while working from home (see Section 3.4.3). We see complaints from developers about their struggle with unusable two factor authentication systems that their companies have put in place. According to one developer: "*How mush longer do I have to sign into every app I use with 2FA? Not being on the company network is annoying...*" ($R_{2447609}$). The ensuring of a secure application usable within a company network is more of a design problem than a security problem. Design and development of usable security techniques is an active area, which spans both the Academia and the Industry. The struggles of developers with the usability of secure applications shows that we need to educate software developers and designers both the technical as well as usability aspects of software design.

The hardship of working professionals and software practitioners during the COVID-19 pandemic are well-documented through a number of studies. Our study results show that developers still managed to find joys during their daily activities. Those joys mostly came through doing small but meaningful things, such as finding time to read books that previously they did not have time to read, resuming old or starting new side software or other projects, engaging in chats and jokes with online communities of software developers and other like-minded people, finding time to reconnect with families or long-distance loved ones, spending time together to walk at quiet night and to watch movies, and so on. Other than software side projects, none of the other activities are related to software development. Yet, they are profoundly humane.

Physical and mental well-being are important and become more crucial when developers face isolation during the pandemic. Developers are social beings too. Thus, they also cited lack of motivation and loss of productivity during the COVID-19. Developers who will read our report can take solace from our findings that these problems are common among other developers too and thus they cannot punish themselves for loss of productivity due to isolation or other similar problems. We are not the only one to offer this recommendation - similar voice was also heard from Ralph et al. (2020).

While software developers are not as badly affected in terms of job loss as some other professions with regards to job loss, we still find some worrying discussions from developers about losing their jobs. This is particularly concerning when the developers have no saving or safety net to fallback to. We find that these issues are mostly discussed by developers working as consultants or software firms that are working for retail companies. The developers, as well as such software companies, may try to diversify their skills and products to become more pandemic-proof.

While our study findings cannot be analyzed across developer demographics (e.g., country, gender, profession) given the absence of those meta data for all users in devRant, we noticed discussions from developers of different countries as noted in Section 3 (e.g., Australia, Argentina, USA, etc.). We also noticed discussions from developers of diverse backgrounds like employees from software companies, freelancers, etc. While developers in devRant are not required to disclose their gender, they can pick an avatar with visual features commonly associated with women or men. Among the users in the discussions we studied, we observe those preferring either of the avatar kinds. It is true that some of the findings are applicable to developers from all backgrounds, e.g., isolation or interruptions at work. It is also true that some other findings may be more applicable to females (e.g., household chores in some countries). Therefore, our study findings can be considered as starting points to distill insights about developers in general from a developer forum like devRant. Specific analysis across demographics will require surveys of targeted population. In particular, the applicability of our study findings within industrial contexts are intuitive for several key areas as follows:

- ***Micromanagement***. Organizations can train managers to be more empathetic to the problems developers during remote working. As we find quotes from developers in our study, they report constant interaction over zoom/Skype with managers to be detrimental to their mental and physical health during remote work. Organizations can train the managers and developers to build relationships based on mutual trust and clearly defined tasks, goals, and deadlines.
- ***Productivity***. Our findings show that the pandemic can have multi-faceted impact on the productivity of developers. While some developers expressed joy at working from home, some others expressed their lack of motivation and thus a loss in productivity. This finding is also corroborated by Ford et al. (2020) in their study of developer productivity at Microsoft during COVID-19. Our finding denotes that organizations need to tailor different wellness program depending on employee needs and problems to reduce the drop in productivity. For example, we find that developers who are isolated at home were appreciative of having to share their situations and discussing their life with other developers in devRant. We also see that developers recommended using online chatbots to address isolation. Therefore, platforms like devRant can help. Companies can create such internal open platforms (and chatbots) for their employees. Company specific benefits can be offered to developers who expressed their problems in such platforms.

- ***Technology.*** We find evidence of developers having problems with their setup of home office, their access to internet and their remote access to classified company data remotely. Organizations can create more resilient and secure remote software system to address those needs.
- ***Lockdown Preparedness.*** Coping strategies and pandemic awareness are major topics of discussions among the developers in devRant. Such discussions can be intuitively applicable to all developers. Companies can take notes of the various coping strategies reported in our study and devise policies and/or systems to support their employees during their work from home.

Software Engineering Researchers. While working from home, developers in our dataset reported to get stuck due to the lack of communication with their team members. They searched for software documentation to mitigate such problems. However, they also found that the software documentation are frustratingly missing or of low-quality. This problem is not surprising. While proper and sufficient software documentation is crucial to the learning and development of software, previous research in software engineering finds that software official documentation is often found to be incomplete, incorrect and obsolete (Uddin and Robillard 2015; Robillard and DeLine 2011). The needs for good software documentation become even more crucial during situations like a pandemic, when developers cannot easily connect with anyone they need to develop their software. In such cases, their only reliance becomes the software documentation. Despite efforts spent in software engineering research to produce and/or improve software documentation, our study shows that developers were not happy with software documentation during the pandemic. The software engineering research community thus can devote more research efforts to develop efficient tools and techniques to automatically produce and improve software documentation. In addition, empirical research in software engineering can study the impact of pandemic on developers' productivity and well-being by studying the large amount of developers' discussions in online forums related to their job loss, isolation, etc.

5 Threats to Validity

We discuss the threats to validity following guidelines for empirical studies (Wohlin et al. 2000).

Construct validity threats concern the relation between theory and observations. In our study, they could be due to the errors in measurement. The accuracy of the open coding is subject to our ability to correctly detect and label the categories. The exploratory nature of such coding may have introduced the researcher bias. To mitigate this, both authors jointly spent three weeks' time to label the posts. The process often resulted in in-depth analysis between the two co-authors of the posts, the comments provided to the posts, and in some cases the links shared in the posts. A final label is only provided when the authors were confident of the label after such in-depth analysis and discussions. During the card sorting, each post is considered a card. Another approach would have been to further divide the contents of a post into multiple quotes, where each quote denotes an aspect. We did not do this based on the observation that the understanding of an aspect often required the consultation of the entire post (and sometimes the comments associated with it), even when the post contained discussions of multiple aspects. To the end, treating each post as a card

was found to be the most effective during the labeling. The entire open coding was done virtually due to the pandemic.

Threats to internal validity refer to how well the research is conducted. In our case, it is about how well we followed the guidelines of open coding during our manual analysis of the posts. The first author has extensive background on conducting and analyzing developer discussions and responses using open coding (Uddin et al. 2019; Uddin and Robillard 2015). The second author has extensive background on software engineering, design and processes. The authors discussed follow the guidelines of qualitative study by Corbin and Strauss (Corbin and Strauss 2008) during their analysis of the results. A high internal validity in the design can let us choose one explanation (e.g., topic assignment) over another (e.g., not relevant to any COVID related topic) with a high degree of confidence, because it avoids (potential) confounds.

Threats to external validity compromise the confidence in stating whether the study results are applicable to other groups. Our results are based on developers' discussions in the online devRant platform. The site is used by software developers from different countries across continents (Asia, Australia, Europe, North America, etc.) We have also seen discussions from developers from diverse backgrounds like open source, freelancers, software companies, consulting firms.

As we noted in Section 1, a post in devRant is called a 'rant'. Our observation of devRant posts during our study finds that the term 'rant' may create a wrong impression that all the posts in devRant are 'negative', given a 'rant' is intuitively associated with 'angry'/'negative' comments. However, the front page of devRant notes that "*Join a fun community of developers - share and bond over successes and frustrations with code, tech and life as a programmer*". Indeed, as we also noted in our study findings, we find both positive and negative sentiment polarities in the discussions of developers that are attributed to COVID-19. A pandemic like COVID-19 has affected many aspects of our life and software developers also encountered many obstacles to cope with the pandemic. Therefore, we find that around 49.2% of all posts in our study contained negative sentiment. However, we also find 25.2% of all posts containing positive sentiment. This observation corroborates to the mission statement of devRant that developers on the platform share both their successes and frustrations. Therefore, 'ranting' in devRant can contain positive or negative sentiment, despite the general notion of 'ranting' being associated with negative polarities only. Despite the above findings, we note that the word 'rant' generally associates with frustration and sarcasm. Therefore, devRant users may be tempted to use this site to share their frustration mostly. While we cannot verify this fully using our COVID-19 related datasets, we understand that simply sharing of frustrations and sarcasms may constitute bias towards negative comments around the topics we observed.

Our study results are based on the qualitative analysis of devRant posts, because we find that discussions in devRant are focused on technical, non-technical, and social aspects of developers' life. Developers can share non-technical or social aspects of their life in other platforms like Reddit, Quora, and Twitter. However, unlike devRant, all those platforms do not focus exclusively on software developers. As such, anyone can share information in a general-purpose social platform like Reddit, Quora, and Twitter and he/she does not have to a software developer. In contrast, a user is devRant is a software developer. Therefore, we can expect to find more reliable and less noisy data about various aspects of software developers' life from devRant than other platforms like Reddit, Quora, or Reddit. A detailed comparison of COVID-19 related findings across the various online forums needs more than a single paper. We leave it as our future work.

As we noted in Section 4.1, our results find evidence similar to previous studies. This similarity is a confirmation that the developers in our dataset were going through experiences similar to the the developers participated in the two previous studies. This confidence is important, because we have also reported additional findings that were not not reported in previous studies (see Section 4.1). We, however, cannot offer a breakdown of our study findings along developer demographics, such as age, gender, and profession type. Such breakdown was not the focus of our study. Rather, we wanted to learn about the overarching problems and joys of software developers during the pandemic. Our findings thus offer an overview of the underlying phenomenon. However, similar to other SE COVID-19 studies, our study also cannot be expected to directly applicable to any group of software developers that may not have gone through similar ordeals.

6 Related Work

Related work can broadly be divided into three categories: (1) SE research related to COVID-19 (Section 6.1), (2) Research on developers' productivity and wellbeing (Section 6.2), and (3) Research on teleworking (Section 6.3).

6.1 Software Engineering Research Related to COVID-19

The first paper at the EMSE journal on SE research related to COVID-19 was arguably published by Ralph et al. (2020). In July 2021, we took a note of all SE research papers that cited Ralph et al. (2020). We use Google scholar to find the list of such papers, which returned us with a list of around 27 papers. Out of the papers, we discarded seven papers because some of those were duplicate of each other (i.e., we kept only one from a duplicate list) (2) and others were not related to SE research. The 20 related SE research papers can broadly be divided into the following categories: (1) Survey of software developers, (2) Empirical study of code repositories and COVID-19 apps, (3) Empirical study findings validated in survey, and (4) Qualitative analysis of software development practices. We discuss the papers below. We compared our study findings with the papers in Section 4.1.

- **Surveys of software developers.** The related papers conducted surveys involving developers from: (1) Multiple countries, (2) A single country, or (3) A particular software organization,

  (1) ***Surveys involving developers from multiple countries.*** We find two papers that explicitly noted the participation of software developers from multiple countries (and potentially multiple software organizations).

  Ralph et al. (2020) surveyed 2,225 developers from 53 different countries and asked them questions about how their productivity and wellbeing are affected by COVID-19. They found that in general productivity and wellbeing have declined and they are closely related. This means that lack of wellbeing can impact a loss in productivity. They also found heterogeneity in the needs of the developers from their organizations, i.e., different people expected and needed different types of support. They also find that the pandemic may have affected more severely women, parents, and people with disabilities. Russo et al. (2021a) studied the typical daily life of software developers during the COVID-19 pandemic. They conducted a two-stage longitudinal study involving around 200 sampled software developers from across the globe. They find that most of development works done

by software engineers remain the same before and during COVID-19, even though they worked remotely during the pandemic. However, the find that the amount of time the developers spent on each development activity during the pandemic was not correlated ot their well-being and productivity. They conclude that it was not challenging for software developers to work remotely during COVID-19.

(2) ***Surveys involving developers from a single country.*** We find five papers, four surveyed software developers from Brazil and one from Bangladesh.

Oliveira et al. (2020) surveyed 413 Brazilian software developers to study the impact of COVID-19 and found that the perceived productivity of the developers increased during the pandemic, mainly due to lower number of interruptions from peers. Bezerra et al. (2020) conducted a survey of 58 Brazilian software teams to understand the human and organizational factors that influenced software teams during COVID-19. They found that 74% of the participants considered their productivity remained good during the pandemic and more than 84% considered they had good communication with co-workers. de Mendonca et al. (2020) conducted an experiment to understand the main differences between the procedures Brazilian developers expected to follow before the pandemic and the procedures they followed during the pandemic. They find that although software development teams quickly adapted to the pandemic situation, they experienced some impacts of pandemic on several factors like trying to reconcile the trade-offs between completeness and the tightness of the first release. Machado et al. (2021) compare the impact of remote working on Brazilian male vs female software engineers. They find that women face lack of support with housework and child care responsibilities.

Ganguly et al. (2020) conducted a survey of IT professionals in Bangladesh and found that the most affected issues of the IT professionals during the COVID-19 due to working from home are related to resource and work space. Around 60% of the respondents reported that their cooperation with other employees remained unchanged or even increased during the period.

(3) ***Surveys involving a particular software organization***. We find six papers that explicitly noted the scope of their survey to be within an organization. Five of those came from multiple branches of Microsoft (e.g., Microsoft China, USA, etc.). The other paper came from Ocuco Ltd, a globally distributed software company.

Extensive studies are conducted at Microsoft to understand impact of COVID-19 on software developers and the development processes during COVID-19. Butler et al. (2021) report that that almost equal number (34%) of Microsoft software developers found it more or less productive while working remotely in a March survey. A later survey found a bit more developers finding remote working less productive. Overall, when compared with the overall US workers, the findings show that slightly more developers at Microsoft found remote working productive. The authors attribute this higher number in Microsoft due to the prior experience of Microsoft developers to work remotely. Overall, the authors conclude that remote working has several problems like struggling with healthcare, problems of managers dealing with increased volume of remote communication with employees, and so on. Rodeghero et al. (2021) surveyed 267 new hires at Microsoft that onboarded to various software development teams at Microsoft during the COVID-19 pandemic. They found that most of those new hires onboarded

remotely and never had an opportunity to meet their peers in person. This lack of in-person socialization created the biggest challenges for them. To address the challenges, they recommended to promote communication, to schedule 1:1 meetings, to emphasize on team building, etc. Miller et al. (2021) conducted an exploratory study of two surveys involving total 2,265 developers to investigate the impact of COVID-19 on software team culture and productivity. Their qualitative analyses find that communication and social connection were affected. For example, peers used phrase like 'How was your weekend?' to inquire about each other to show support. Russo et al. (2021b) conducted a longitudinal study of 192 software developers by covering over 50 psychological, social, situational, and physiological factors related to wellbeing and productivity. They find that the quality of social contacts can be positive predictors for wellbeing and productivity, while boredom and distractions are negatively correlated to productivity. Overall, they find that no predictor variable was strong enough to infer any causal variance on productivity and wellbeing. Wang et al. (2021b) surveyed software developers at Microsoft China during the later phases of COVID-19 when companies adopted a hybrid mode, i.e., developers could decide to divide their time working remotely or at office. They find that the time arrangements between home and office are diverse: around 10.7% respondents worked from home fully, 20.2% worked from office fully, and the rest 70% adopted a hybrid mode. The employees found it challenging to shift from home PC (Personal Computer) to office PC and asked for better technological support in future.

NicCanna et al. (2021) describe the positive impact of globally distributed development practices at Ocuco Ltd during COVID-19, a medium-sized organization headquartered in Ireland. They report little change in their process during COVID-19, because they already were working in remotely since 2016. They also cited their advantage of using Scaled Agile Framework (SAFe) during the pandemic.

- **Empirical study of code repositories and COVID-19 apps.** We find three empirical studies of code repositories using open source/organization data. Bao et al. (2020) focused on understanding wellbeing and productivity of Baidu employees while working from home. The paper quantitatively analyzes 4,000 records (e.g., code commits, reviews, etc.) of 139 developers' activities. Contrary to Ralph et al. (2020), they found that work from home has both positive and negative impacts on developers' productivity in terms of different metrics, such as number of commits. Rahman and Farhana (Rahman and Farhana 2020) studied bugs in open source projects related to COVID-19. They identified 8 categories of bugs in 7 different kinds of projects. Wang et al. (2021a) report an empirical study of 4,322 COVID-19 themed Android apps (2,500 unique), out of which 611 are potential malware samples (370 unique). Most of the apps and malwares were released after March 15, 2020 and are disguised as fake official apps. The malwares are mostly of two types: Trojan and Spyware. That means the main purpose of the malwares is to steal information by phishing and to extort money from victims.
- **Empirical Study + Survey.** Silveira et al. (2021) conducted one empirical study followed by a survey. First, they mined 100 GitHub projects and compared 10 different metrics in the projects before and during COVID-19, e.g., number of active contributors, number of commits or bug fixes, etc. They then confirm or validate the results via

the survey. They find both agreements and disagreements between the survey responses and the findings from the 100 GitHub projects. For example, they observed a decrease in the number of bug-fix during COVID-19 in the GitHub projects but the survey participants disagreed with the finding. The survey participant also noted that working from home during COVID-19 did not impact their code quality, but they cited sleep disorder during the pandemic.

- **Qualitative analysis of software development practices.** We find three qualitative studies of software development processes/applications during COVID-19. Connor et al. (2021) apply the temporal complexity theory to remote working based on results from field studies with ISD (Information System Development) professionals. They find several issues like lack of communication between the lead and employees while working remotely, mismanagement of types and time and social constructions, etc. Butt et al. (2021) studied agile project development issues during COVID-19. They interviewed software developers from several industries to understand the significant reasons for the failure of agile methodology. Ozkaya (2020) discussed the impacts of uninterrupted scenarios that software developers experienced during COVID-19 by reflecting on software engineering practices after the first four months of the pandemic. Ozkaya argues that organizations that practiced agile development before the pandemic fared better during the pandemic.

6.2 Research on Developers' Productivity and Wellbeing

6.2.1 Developers' Productivity

Significant research efforts have devoted to understand the factors affecting developers' productivity (Meyer et al. 2014, 2017a; Nguyen et al. 2011; Albrecht 1979; Paiva et al. 2010; Ko 2019; Perry et al. 1994; Baruch 1996; Chong and Siino 2006; Czerwinski et al. 2004; Parnin and DeLine 2010; Girardi et al. 2021; Forsgren et al. 2021). The assessment of productivity is a multi-faceted problem, as the originally observed by Albrecht (1979) who formulated a productivity measure at IBM based on several key variables to projects. A literature review by Paiva et al. (2010) identified 35 influence factors on developers' productivity, such as capability and experience, knowledge, diversity, clear goal, cohesion and team communication, etc. Nguyen et al. (2011) find in 2011 that average software productivity has increased by six times over the last 40 years.

Recently, Sadowski et al. (2019) proposed a software development productivity framework by focusing on three dimensions: velocity (how fast work gets done), quality (how well work gets done), and satisfying (how well it was perceived). Previously, Meyer et al. (2014) found that developers perceive their days as productive when they complete many or big tasks without significant interruptions or context switches. However, the observational study showed that developers still performed significant and big tasks while being interrupted. In general, interruptions can be disruptive to the productivity of software developers, especially while they work alone instead of in a team (e.g., pair programming) (Chong and Siino 2006). Czerwinski et al. (2004) report on a diary study of the activities of software developers to understand and characterize how people interleave multiple tasks amidst interruptions. Parnin and DeLine (2010) look for cues on how developers resume work after they are interrupted. They surveyed 371 programmers on their nature of tasks, interruptions, task suspension, and resumption strategies. They found that developers rely on heavy note-taking activities across several types of media to help them resume their interrupted work.

In two follow up studies, Meyer et al. (2017a, b) characterized the perceptions and productivity and developed tools to improve productivity. In surveys of 413 developers at Microsoft, Meyer et al. (2017a) identified six groups of developers with similar perceptions of productivity: social, lone, focused, balanced, leading, and goal-oriented developers. At the same time, Meyer et al. (2017b) analyzed the impact of self-monitoring to improve the productivity of knowledge workers. They studied 20 software developers through a user-feedback driven development approach and surveyed 413 developers to infer design elements for workplace self-monitoring. A preliminary cognitive support framework based on bots was discussed by Storey and Zagalsky (2016). Constant monitoring of interruptions and offering support via simple dimming of LED lights to reduce the interruption were also found to increase the productivity of the developers (Züger et al. 2019).

Like other professions, the COVID-19 pandemic has also negatively affected the productivity of software developers. Ralph et al. (2020) recommended organizations to not rely on traditional measures of software productivity during COVID-19. This recommendation is timely, because as Baruch (1996) finds, there is a correlation between an employee's self-appraisal and his/her direct manager's appraisal. As such, organizations may need to instead ask the developers to self-judge their productivity during the COVID-19. Indeed, Ko (2019) urged not to quantify productivity because such quantification can warp incentives if not measured well or can influence sloppy management to make bad decisions.

In our study, we find that the physical and mental health concerns of software developers can negatively impact their productivity, which can degrade their motivation to work. This, coupled with micromanagement can further exacerbate the loss of productivity. Our findings thus offer additional evidence that we may need new ways of measuring developers' productivity during a pandemic like COVID-19. Indeed, Jaspan and Sadowski (2019) argue for diverse metrics to measure productivity, since no single metric can properly capture the diverse productivity dimensions and developers' needs.

6.2.2 Developers' Wellbeing

While SE research has focused extensively on developers' productivity, research on the wellbeing of software developers and the factors affecting developers' wellbeing is limited. In general, developers' are not happy when they are interrupted (Meyer et al. 2014). In general, interruptions are perceived as disruptive to task completion, because it can negatively affect the mental state of a user (Bailey et al. 2001). While interruptions at office can be more than at while working from home, the findings of Perry et al. (1994) show that software developers spend significant time with their coworkers on non-coding activities, such as chats and in-person communication. They also find that the reluctance of developers to use emails can impact the development processes. The push towards everything remote and online during the pandemic has taken out all such daily moments of joy from the life of a software developer. As such, they can feel demotivated while working alone. Indeed, we find direct evidence from multiple developers in our dataset that they are less motivated while working from home. Interestingly, Chong and Siino (2006) find that developers are more resilient to interruptions while working in pair. Developers' wellbeing can be better supported by making them more happy, which in turn is necessary to make them productive. Indeed, Graziotin and Fagerholm (2019) argue that making software developers happy is very important to improve their productivity.

6.2.3 Sentiment Analysis in Software Engineering

Closely related to topics of productivity and well-being is the research on sentiment and emotions expressed by software developers. In our work we followed the emotion taxonomy of Shaver et al. (1987) that has been previously used by Calefato et al. (2018). Manual labeling of sentiment has been carried out in the past for such software engineering texts as Jira issues (Kaur et al. 2018), Gerrit code reviews (Ahmed et al. 2017), Stack Overflow posts (Calefato et al. 2018), and source code comments expressing self-admitted technical debt (Fucci et al. 2021). In a related line of research the authors have considered emotions, such as joy or sadness (Ortu et al. 2016; Novielli et al. 2018), excitement or depression (Islam and Zibran 2018). Beyond manual annotation multiple tools have been proposed to automate the sentiment analysis task (Ahmed et al. 2017; Calefato et al. 2018; Islam and Zibran 2017, 2018). However, performance of these tools is known to drop when applied to data from different data sources (Novielli et al. 2020), and since none of the tools has been designed for devRant we had to resort to the manual annotation. For a more extensive discussion of sentiment analysis for software development we refer to the recent systematic literature review of Lin et al. (2022).

6.3 Research on Teleworking

Recently, Dingel and Brent did a survey and found that 91% of developers are now working from home full time (Dingel and Neiman 2020). The socio-technical aspects of working from home are studied in diverse fields (Olson and Olson 2000), across genders (Teo and Lim 1998; Tremblay 2002; Wilson and Greenhill 2004; Sullivan and Lewis 2001; Gothoskar 2000), by analyzing telecommuters attitudes, social interactions, work-life balance, and so on (Baruch 2000; Hill et al. 2003; Perry et al. 2018; Duxbury et al. 1998; Neufeld and Fang 2005; 2004)

Neufeld and Fang (2004, 2005) analyzed the productivity of remote workers. They conduct semi-structured interviews of 32 telecommuters and then survey 100 telecommuters of two organizations. They find that telecommuter beliefs and attitudes and the quality of their social interactions with the managers and family members, are all strongly associated with their productivity. Duxbury et al. (1998) analyzed the role telework and its impact on maintaining the balance between work and family. They find that the working from home helps employed parents balance work and family demands. Perry et al. (2018) tested person and job factors as important considerations in remote work and find that employees with high emotional stability and high autonomy can be best positioned, even under stress and during frequent remote work. Baruch (Baruch 2000) analyzed the benefits and pitfalls of teleworking as perceived by professionals and managers. Interviews of 60 British teleworkers showed that working from home did not affect the employees, but time management is crucial and reductions of distractions while working from home can be an added benefit. Hill et al. (2003) analyze perceptions of employees, and do direct comparisons between employees working in traditional vs virtual offices using multivariate analyses. They find that the influence of the virtual office is mostly positive on aspects of work but somewhat negative for aspects of family and/or personal life. Overall, the attitudes and perceptions towards teleworking vary between males and females (Teo and Lim 1998). Tremblay (2002) find that women are frequently in a situation of less autonomy than men in telework, and Gothoskar (2000) argue that the problems women face can have diverse and complex implications.

In general, distance matters during teleworking (Olson and Olson 2000) and teleworking can have heterogeneous impact depending on the gender, perception, and work-life balance. This finding is also corroborated by Ralph et al. (2020) for software developers that the pandemic may have disproportionately impacted the women, parents and people with disabilities. However, within a global software development landscape, prior to the pandemic, Johri (2013) finds that several software developers reported to have an increase in productivity and efficiency due to teleworking.

We cannot confirm the findings of Ralph et al. (2020) on the impact of teleworking on the female software developer, because we cannot reliably identify the gender of a user in devRant. However, similar to Johri (2013), we also find that some developers expressed their happiness due to teleworking. Some of them were happy because they do not have to commute anymore, some reported to have less distractions while at home, some appreciated the flexibility to be with their pet or to be on their informal clothing. Some developers even expressed their happiness to be able to do household chores in between their works, because they are always at home.

7 Conclusions

We report a qualitative study of developers discussions in online platform devRant to understand the diverse technical and non-technical aspects that software developers experienced during the early periods of COVID-19. We observed a total 19 topics related to the various aspects of software developers' lives that we group into six categories: Workplace & Professional aspects, Personal & Family wellbeing, Technical Aspects, Lockdown preparedness, Financial concerns, and Societal and Educational concerns. While around 49% of the discussions contain negative sentiment polarity, around 26% contain positive polarity. We find evidence of developers' stress to cope with this unique situation, stories of their job loss with little or no savings to fallback to. Yet, we find remarkable evidence of developers' positivity to support each other and to support the COVID-19 awareness by leveraging their skills. Our study findings can offer benefits to multiple stakeholders in SE to prepare for future such pandemic or emergency situations (e.g., sudden work from home due to a natural disaster). Software organizations and researchers can use our findings to make policies and tools to improve development activities, practices, and the lives of software developers - for example, to better prepare for a future pandemic.

Our future work will focus on the following major directions: (1) Analysis of co-occurred tags along with our COVID-19 related tags. A total of 525 other tags co-occurred with our 30 COVID-19 related tags. The tags refer to diverse platforms and operating systems like 'GitHub', 'Android', 'Windows', 'Google Cloud', etc. The tags also refer to their work atmosphere like 'micromanagement', 'managers' etc. Our future work can focus on identifying all the posts related to these *other* tags to analyze topics of discussions in the posts. (2) Analysis of comments to posts in devRant to derive a deeper understanding of the 19 topics we observed. While we checked comments to a post during our labeling of the post with a topic, we did that to understand the underlying context of the post. Each comment to a post can have more insights than the original post context, which may offer the complex nature of the observed topics and their interactions with each other. (3) A comparison of the findings between the early and later phases of COVID-19 data using COVID-19 discussions in devRant since January 2020 till now. Such a comparative analysis can further complement the findings of Ford et al. (2020), who conducted a longitudinal study

of Microsoft developers to understand their productivity and other factors during the early vs later phases of COVID-19. (4) A comparison of the findings regarding the various topics related to developers' lives between pre- and during-COVID periods. This can be done by conducting a comparative survey of existing SE literature on developer productivity and wellbeing between pre- and during-COVID periods. Further analysis can focus on the analysis of developer discussions in devRant between pre and during-COVID periods. (5) A comparison of findings from devRant against those obtained from other platforms like Reddit, Twitter, and Quora.

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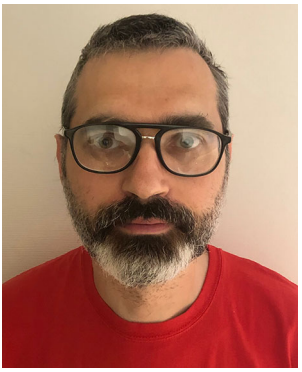

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